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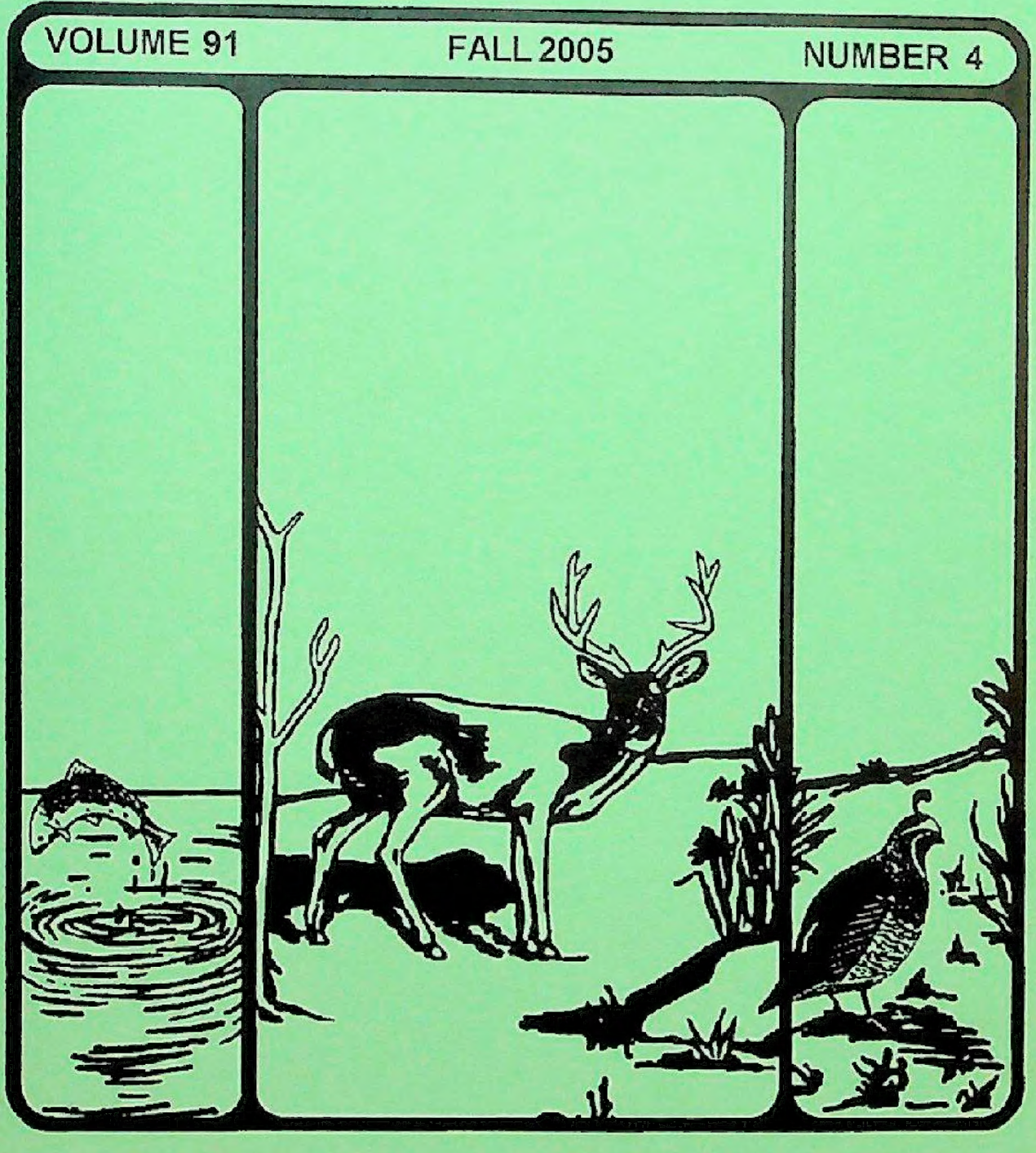

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CONTENTS

ARTICLES

Historical Status of Coho Salmon in Streams of the Urbanized San Francisco Estuary, California ..... Robert A. Leidy, Gordon Becker, and Brett N. Harvey 219

Giant Garter Snake Surveys at Some Areas of Historic Occupation in the Grassland Ecological Area, Merced Co., and Mendota Wildlife Area, Fresno Co., California ..... Catherine Dickert 255

Pintail Distribution and Selection of Marsh Types at Mendota Wildlife Area During Fall and Winter ..... Joseph P. Fleskes, David S. Gilmer, and Robert L. Jarvis 270

NOTES

A Simple One-Way Door Design for Passive Relocation of Western Burrowing Owls ..... Howard O. Clark, Jr and David L. Plumpton 286

REFEREE ACKNOWLEDGMENTS 290

INDEX TO VOLUME 91 291

California Fish and Game 91(4):219-254 2005

HISTORICAL STATUS OF COHO SALMON IN STREAMS OF THE URBANIZED SAN FRANCISCO ESTUARY, CALIFORNIA

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ABSTRACT

The historical status of coho salmon, *Oncorhynchus kisutch*, was assessed in 65 watersheds surrounding the San Francisco Estuary, California. We reviewed published literature, unpublished reports, field notes, and specimens housed at museum and university collections and public agency files. In watersheds for which we found historical information for the occurrence of coho salmon, we developed a matrix of five environmental indicators to assess the probability that a stream supported habitat suitable for coho salmon. We found evidence that at least 4 of 65 Estuary watersheds (6%) historically supported coho salmon. A minimum of an additional 11 watersheds (17%) may also have supported coho salmon, but evidence is inconclusive. Coho salmon were last documented from an Estuary stream in the early-to-mid 1980s. Although broadly distributed, the environmental characteristics of streams known historically to contain coho salmon shared several characteristics. In the Estuary, coho salmon typically were members of three-to-six species assemblages of native fishes, including Pacific lamprey, *Lampetra tridentata*, steelhead, *Oncorhynchus mykiss*, California roach, *Lavinia symmetricus*, juvenile Sacramento sucker, *Catostomus occidentalis*, threespine stickleback, *Gasterosteus aculeatus*, riffle sculpin, *Cottus gulosus*, prickly sculpin, *Cottus asper*, and/or tidewater goby, *Eucyclogobius newberryi*. We found evidence for the occurrence of coho salmon in eight watersheds characterized by the coast redwood, *Sequoia*

***sempervirens*, riparian community. These conditions are more typical of the high rainfall coastal streams directly tributary to the Pacific Ocean that historically had relatively high abundances of coho salmon. All streams known or suspected historically to support coho salmon are characterized by cool summer water temperatures, suitable spawning and juvenile rearing habitat, distinct surface water connections to the estuarine and marine environments, as well as stream flows during the months of February through May suitable for smolt out-migration.**

INTRODUCTION

Assessing the historical status of anadromous salmonids in urbanized environments is difficult because many of the natural habitats and processes important to their survival have been dramatically altered or are no longer present. The task is even more difficult for those species at the edge of their historical geographic range, where population abundance may be naturally low in comparison to the distributional center of their range. Additional complications in any historical assessment is determining what, if any, were the effects of widespread plantings of hatchery salmon in California during the 19th and 20th centuries. Such is the case for coho salmon, *Oncorhynchus kisutch*, an endangered species of salmonid that historically occurred in streams tributary to the San Francisco Estuary (Estuary), California.

Coho salmon historically were distributed in coastal streams of California from the Smith River, Del Norte County, south approximately 560 km to at least the San Lorenzo River, Monterey County (Moyle 2002, B. Spence, National Marine Fisheries Service (NMFS), personal communication). Recent status reviews indicate that natural populations of coho salmon within the Central California Coast Evolutionary Significant Unit (ESU) have declined dramatically over the last 50 years, and populations continue to decline in certain regions (Brown et al. 1994, NMFS 2001, California Department of Fish and Game (CDFG) 2002). The Central California Coast ESU includes populations of coho salmon from Punta Gorda in northern California south to, and including, the San Lorenzo River, in central California, as well as tributaries to the Estuary, excluding the Sacramento-San Joaquin River system in the Central Valley. In 2004, the National Marine Fisheries Service proposed changing the status of coho salmon in the Central California Coast ESU from threatened to endangered under the Endangered Species Act (NMFS 2004). Also in 2004, the California Fish and Game Commission listed coho salmon populations south of Punta Gorda as endangered under the California Endangered Species Act (http://www.dfg.ca.gov).

Historical records suggest that coho salmon occurred in the Sacramento River system, where it was considered the rarest of the five salmon species known to inhabit the Central Valley (Hallock and Fry 1967, Brown et al. 1994). The McCloud River, a major tributary to the upper Sacramento River, probably supported the most inland population of coho salmon in California prior to the completion of Shasta Dam on the Sacramento River in 1944 (Moyle 2002). There is archaeological evidence that Native Americans may have captured coho salmon from several Estuary streams (Gobalet et al. 2004). Coho salmon also historically occurred in streams of the Estuary where they were last

documented in the early-to-mid 1980s (Leidy 2004).

Little reliable documentation of coho salmon within Estuary watersheds exists, and existing regional status reviews and distributional information for the species provide incomplete information (e.g., NMFS 2001, CDFG 2002). Lack of documentation of coho salmon in Estuary streams is likely explained by several factors, including 1) the scarcity of coho salmon relative to steelhead, and, in San Francisco Bay, Chinook salmon, even though habitats suitable for coho salmon were available historically in some streams surrounding the Estuary, 2) limited sampling of suitable coho salmon habitats prior to substantial habitat modification and associated population declines, and 3) misidentification of juvenile coho salmon as steelhead. The paucity of information contributed to a perception that coho salmon were neither abundant nor important members of Estuary fish assemblages. Consequently, priorities for salmon restoration in the Estuary have been focused historically on species such as steelhead that were relatively widespread and abundant within the Estuary and, unlike coho salmon, continue to maintain small populations in many Estuary tributaries (Leidy et al. 2005). Information collected during this study suggests that coho salmon may have been more widespread in Estuary watersheds than collection records indicate.

Recovery planning efforts by federal and state agencies for coho salmon within the Central California Coast ESU requires an assessment of their historical status. Therefore, the purpose of this paper is to document the historical distribution of coho salmon in streams tributary to the Estuary.

STUDY AREA

The Estuary is the largest along the Pacific coasts of North, Central, and South America. It is an inland estuary lying between more mesic, cooler Pacific Coast Range streams that drain directly to the Pacific Ocean, and the more xeric, hotter Central Valley. The former are characterized by a historically relatively high abundance of coho salmon, while the latter lies at the historical edge of the coho salmon range (Moyle 2002). Streams tributary to the Estuary are considered part of the Sacramento-San Joaquin Zoogeographic Province based largely on their shared fish faunas (Hopkirk 1973, Leidy 1984, Moyle 2002). Estuary tributaries differ in part from other Central Valley streams because of the more direct marine influence that affects fish assemblage membership. Thus, the species composition of fish assemblages in Estuary streams resembles both Central Valley and coastal streams immediately north and south of the Golden Gate (Leidy 2004).

Sixty-five local watersheds surround the Estuary, and are the focus of this study. Estuary watersheds cover a maximum linear distance of 212 km from north (38°, 39', 34" N) to south (37°, 01', 34" N), and 90 km from east (121°, 24', 24" W) to west (122°, 43', 52" W). Watersheds range in area from 2.8 km^2 to 1813 km^2. Study area watersheds lie within portions of 7 U.S. Department of Agriculture Forest Service ecological sections and 14 subsections (Miles and Goudey 1997). These sections and subsections are derived from a national hierarchical classification based on factors such as climate, physiography, water regime, soils, air, hydrology, and potential natural communities

Table 1. Streams tributary to the San Francisco Estuary with historical evidence supporting the occurrence of coho salmon by date or period of record, evidence type (MS = museum specimen. MR = museum record. SS = stream survey, including standard collection techniques such as electrofishing, seine, fyke, tow or dip-net, or snorkeling. OBS = direct observational account. AA = anecdotal account. SH = suitable habitat present), historical status, and reference or source. Streams are listed in clockwise direction around the Estuary beginning in Contra Costa County.

Watershed, County	Period or record date	Evidence type	Historical status[1]	Reference(s)/Source(s)
(1) Walnut-San Ramon, Contra Costa	Prehistoric; 1950s to mid-1960s	MS[2], AA, SH	PR	CDFG[2,3] 1977; Leidy 1983; Gobalet et al. 2004; Leidy 2004
(2) San Pablo, Contra Costa	Prehistoric; 1940s to 1950s; pre-1957	MS[2]?, AA, OBS, SH	PR	Evans[4] 1957; Needham and Gard 1959; C. Leggett, personal communication 1976; Nakaji 1975; Gobalet 1990, 1994; Gobalet et al. 2004; Leidy 2004
(3) Strawberry, Alameda	Prehistoric; pre-1939	MS[2], AA, OBS, SH	PR	Shapovalov[5] 1939; Follett 1975; Charbonneau and Resh 1992; Gobalet et al. 2004; Leidy 2004
(4) Temescal Creek, Alameda	Prehistoric; late-18th to early 19th centuries	MS[2], AA?, SH	PR	Schenck 1926; Louderback 1940; Follett 1975; Broughton 1997; Gobalet et al. 2004; Leidy 2004
(5) San Leandro, Alameda-Contra Costa	1877; prior to 1957; likely circa late-1920s	SS, OBS, SH	PR	Evans[4] 1957; Needham and Gard 1959; Leidy 2004 to early-1930s
(6) San Lorenzo, Alameda	Pre-1960s	AA, SH	PS	Skinner 1962; ACFCWCD 2002; Grossinger and Brewster 2003; Leidy 2004

(7) Alameda, Alameda	Late-1930s; early-to-mid-1960s	AA, OBS, SH	DF	Skinner 1962; J. Hopkirk, personal communication 1981; Alameda Creek Alliance[6] 2002; Leidy 2004
(8) Coyote, Santa Clara	Prior to mid-1950s	AA, OBS, SH	PR	Skinner 1962; Smith 1998; Leidy 2004
(9) Guadalupe-Los Gatos, Santa Clara	1920s-1960s	AA, SH	PS	Skinner 1962; Smith 1999; SCBWMI 2001; Guadalupe-Coyote Resource Conservation District[7] 2001; Johmann[8, 9] 2002; Leidy 2004
(10) San Francisquito, Santa Clara	Prehistoric; circa 1930s-1940s	MS[2?], AA, SH	PS	Skinner 1962; Guadalupe-Coyote Resource Conservation District[7] 2001; Johmann[8, 9] 2002; Gobalet et al. 2004; Leidy 2004
(11) San Mateo, San Mateo	1860 and 1870s	MS, MR, SH	DF	Museum of Comparative Zoology[10, 11] 1860; Stone 1873; Hallock 1877; Leidy 2004
(12) Arroyo Corte Madera del Presidio, Marin	1940s-1960s, 1981	AA, OBS, SS, SH	DF	Shapovalov 1946; Shapovalov[12] 1946; CDFG[13] 1963; Hallock and Fry 1967; Leidy 1984; Leidy 2004
(13) Corte Madera, Marin	Prehistoric; 1926-1927; 1960s; 1981; 1984	MS[2?]; AA, OBS, SS, SH	DF	California Academy of Sciences[14] 1926; Fry 1936; Follett 1957; Hallock and Fry 1967; Follett 1974; Cronin[15] 1980; Leidy 1984; Emig[16] 1986; Leidy 2004

Table 1 (continued)

Watershed, County	Period or record date	Evidence type	Historical status[1]	Reference(s)/Source(s)
(14) Sonoma, Sonoma	Prior to 1960s	SH	PS	Skinner 1962; Leidy 2004; Sonoma Ecology Center 2004
(15) Napa, Napa	Prior to 1960s	AA, OBS, SH	PS	Skinner 1962; USFWS[17] 1968; Emig[18] 1983; Leidy 2004

[1]Refer to Methods for definitions.
[2]Prehistoric archaeological remains.

(Bailey 1994, Goudey 1994, Miles and Goudey 1997). The relatively large number of ecological subregions and subsections within the Estuary is an indication of the great diversity of ecological community types traversed by study area streams.

Because of its geographic location and complex geologic setting, climate in the Estuary is transitional between the Pacific coastal and Central Valley inland extremes (Leidy 2004). The Estuary's climate is more variable than Pacific coastal and Central Valley environments due to the effects of local physiography and the continuous interaction of maritime and continental air masses. The regional climate is Mediterranean with warm, dry summers (May through September) and cool, wet winters (October through April). About 80% of the precipitation falls between November and February, and it is typically associated with low-pressure cells that produce periods of rain for several days followed by periods of 7-10 days of clear weather (Conomos et al. 1985). Mean annual precipitation ranges from 25-30 cm on the edge of the Central Valley, along the bay flats immediately bordering the Estuary and the Santa Clara Valley, to 152 cm at higher elevations in the Santa Cruz Mountains, Marin County hills and valleys, and Mt. St. Helena volcanic flows and valleys regions. Patterns of temperature and precipitation vary on general gradients of increasing summer temperatures and decreasing precipitation from north to south and west to east; however, even these patterns are moderated by increasing precipitation as well as cooler air and stream water temperatures with increasing elevation. Significant local intra-regional variation in rainfall amounts and patterns depends largely on local physiography. For example, within watersheds traversing the bay flats of Santa Clara and San Mateo counties, rainfall annually may average 30 cm, while rainfall amounts in the Santa Cruz Mountains just 10-15 km to the west (upstream) may average 152 cm, a five-fold difference.

Summer stream water temperatures also follow a general elevation gradient, characterized by decreasing temperatures with increasing elevation. In addition to elevation, water temperatures are affected by the existence of extensive faulting, which produces zones of groundwater discharge (i.e., seeps and springs), especially in the northwest-to-southeast trending Coastal and inner-Coastal ranges that intersect many Estuary watersheds. Zones of groundwater discharge may maintain local water temperatures during summer months at 2-4° C lower than adjacent stream reaches. These zones provide refugia for fish such as rainbow trout, and, historically, coho salmon that require cooler temperatures.

Under conditions of natural surface-hydrology, several conditions likely characterized Estuary tributaries in their lower reaches. Streams with large contributing watersheds or streams flowing from areas of high winter rainfall (i.e., Santa Cruz Mountains, Marin County coastal hills, Mt. St. Helena volcanic flows) typically were perennial to the tidal waters of the Estuary. The lower reaches of other streams within watersheds that traverse valley alluvial deposits maintained flows to the Estuary into April and May. By late spring-to-mid summer these streams became intermittent, depending on variation in annual precipitation. They typically consisted of dry-to-nearly-dry alluvial reaches interrupted by long, deep pools underlain by bedrock, with little surface water connection to smaller tributaries. The middle-to-upper reaches of tributary streams were intermittent-to-perennial in summer depending on characteristics

of local aquifers.

METHODS

Watersheds With Historical Records

We searched historical records for coho salmon as part of studies by the senior author and others on the distribution and ecology of stream fishes and the historical status of steelhead in the Estuary (Leidy et al. 2005, Leidy 2004). We reviewed published literature, unpublished reports, field notes, and specimens housed at museum and university collections and public agency files. Unpublished sources consisted primarily of documents prepared by private consultants for public agencies as required to demonstrate compliance with various environmental regulations (e.g., environmental impact reports and statements, resource assessments, mitigation monitoring reports). To understand the possible influence of fish hatchery plantings on historical observations of coho salmon in Estuary watersheds, we reviewed annual reports for the years 1871-1940 of fish distributions published by the United States Commission of Fish and Fisheries, Bureau of Fisheries, as well as biennial reports by the California State Board of Fish Commissioners, Commissioners of Fisheries of California, California Division of Game and Fish, and CDFG for the period 1870-1966. These documents typically listed annual fish distributions from hatchery facilities for each species by state, county, and/or stream name. We also reviewed unpublished fish stocking records from 1940 to 2004 housed at the CDFG's Silverado Fish Base, Napa County, California. The Silverado Fish Base has responsibility for planting hatchery fish into Estuary watersheds. Finally, we reviewed unpublished Administrative Reports produced by the California Division of Game and Fish and CDFG that listed annual fish production and distribution in California.

Because historical records varied widely in information quality, we developed criteria to rate the relative reliability of historical records in order to assess the likelihood or probability of the occurrence of coho salmon within Estuary watersheds. For purposes of this study, "historical" means prior to 2004. We assigned a definite (DF) category to watersheds for which there is reliable, direct evidence for the occurrence of coho salmon. Direct evidence is from individuals qualified to identify coho salmon. Direct evidence includes collections or first-hand observations made during stream surveys, and contained in published literature, unpublished biological or archeological reports or surveys, and museum collections and records. Direct evidence sources may be combined with other historical information and observations on the current presence of suitable habitat. The current presence of suitable habitat may be a strong indicator of the historical presence of suitable habitat, especially when combined with other forms of evidence. A probable (PR) rating was used for watersheds for which there is no reliable direct evidence for fish use, but there is an assertion of historical use by a qualified individual and we were able to determine that suitable habitat for coho salmon existed historically. This determination was made using information concerning stream habitat characteristics based on reference data, or knowledge of the current presence of suitable habitat. Finally, the possible (PS) rating was assigned to watersheds

for which there is no direct reliable evidence for fish use, but suitable habitat existed historically, or is currently present. Evidence may include anecdotal accounts of the occurrence of coho salmon. Anecdotal evidence of the presence of coho salmon typically consists of unverified personal observations and verbal accounts by individuals with unknown qualifications. Anecdotal evidence typically is the least reliable for confirming the presence of coho salmon, but may be useful when combined with direct evidence. We assigned a PS rating in situations where the qualifications of the individual(s) involved in identifying fish were unknown or unclear.

Historically Suitable Coho Salmon Habitat

The life history and habitat requirements of coho salmon are strict in comparison to other Pacific salmon in California (i.e., steelhead; Chinook salmon, *O. tshawytscha*), which presumably limited the number of streams with historically suitable habitat, especially within the drier, warmer, interior portions of its range in the Estuary. In watersheds for which we found historical information for the occurrence of coho salmon, we developed a simple matrix of five environmental indicators to assess the probability that a stream supported habitat essential for coho salmon survival. Assumptions and environmental indicators that we assessed included the following:

(1) Coho salmon require the presence of an annual, defined surface water connection to tidal waters of the Estuary. Coho salmon exhibit a 3-year life cycle. For populations to persist, adults require annual access to spawning areas and smolts to the ocean environment (Moyle 2002). Only streams with annual surface water connections to estuarine or marine environments through well-defined channels passable to migrating coho salmon would have been likely to support viable populations. The lowermost reaches of several Estuary streams that are located on Holocene alluvial terraces apparently had only intermittent or seasonal connections with marine habitats (San Francisco Estuary Institute[1] 2004, R. Grossinger, San Francisco Estuary Institute, personal communication). While streams with intermittent surface water connections to the Estuary may not have supported coho salmon, these streams may serve as habitat for populations of anadromous and resident rainbow trout that do not require annual access to the ocean to maintain viable populations (McEwan 2001). Therefore, we used historical (circa 1850-1930) topographic maps from various sources depicting stream courses to determine whether there were annual, permanently defined, surface water connections to the marine environment prior to extensive human alteration of watersheds.

(2) Successful spring out-migration of coho smolts requires adequate streamflow conditions during February through May (Hassler 1987, Sandercock 1991). Where available, we reviewed available U.S. Geological Survey streamflow data for daily and mean monthly discharges (cubic feet per second) for the months of February through May, prior to the construction of major dams or water diversions (circa 1898-1950). These data serve as a conservative measure of available unimpaired flows during the

[1]San Francisco Estuary Institute. 2004. EcoAtlas. Oakland, California. http://www.sfei.org.

peak period of coho salmon smolt out-migration.

(3) Adult coho salmon require spawning habitat characterized by the availability of a substrate of suitable size and quality. We considered existing stream reaches with a substrate between 1.3-10.2 cm diameter, and less than 20% fines as suitable for adult spawning coho salmon (Reiser and Bjornn 1979, Bjornn and Reiser 1991). We made no attempt to assess the impacts from land use changes or their effects (e.g., dams, sedimentation) on current substrate composition or quality. Rather, we assumed that the current presence of any suitable substrate for coho salmon is likely to be an indicator of the historical presence of suitable substrate.

(4) Juvenile coho salmon require rearing habitat with adequate water temperatures and pools of sufficient depth containing complex instream, or overhead cover (i.e., boulders, undercut banks, course woody debris, riparian canopy), along stream reaches with gradients not exceeding 5 percent. Juvenile coho salmon prefer habitats where water temperatures for rearing are generally between 12-16° C, and do not exceed 18-20° C for extended periods (Bjornn and Reiser 1991, Welsh et al. 2001, Moyle 2002). While long-term data on stream temperatures is not available for most Estuary streams, we did gather single-event temperature data during summer months when water temperatures are annually the highest and, presumably, the most critical for determining suitability for juvenile coho salmon. We assumed that streams with flowing water and temperatures ranging between 12-18° C during summer months (May-October) were suitable for juvenile coho salmon. We also assumed that juvenile coho salmon required stream reaches with mean water depths greater than 23 cm for rearing (Bjornn and Reiser 1991). In addition, some pools with maximum depths measuring greater than 70 cm must be present (B. Spence, NMFS, personal communication). Mean and maximum water depth measurements were taken within stream reaches and follow the protocol presented in Leidy (2004). Also, we assumed sites suitable for rearing juvenile coho salmon require riparian canopy coverage of > 80%, including trees large enough to provide a source of large woody debris to the stream channel (Flosi et al. 1998). Finally, coho salmon are generally absent from stream reaches with gradients greater than 5%, and are most common at gradients of less than 3% (J. Smith, San Jose State University, personal communication; B. Spence, National Marine Fisheries Service, personal communication). We assumed that stream reaches were suitable for coho salmon if they were characterized by gradients of less than 3% and supported other indicators of suitable spawning and rearing habitat.

(5) Ecological associates such as steelhead, Pacific lamprey, riffle sculpin, and/or tidewater goby were present in Estuary streams with coho salmon. Steelhead, Pacific lamprey, riffle sculpin, and tidewater goby are close ecological associates of coho salmon in coastal Pacific and Estuary streams (Hopkirk 1973, Moyle 2002, Leidy 2004). Steelhead and Pacific lamprey typically require spawning and rearing conditions that overlap broadly with those of coho salmon. We used the presence of one or more of these species as an environmental indicator for the potential presence of coho salmon. In other words, if a stream does not support one or more of these species, then it likely did not contain coho salmon.

Information to assess these environmental indicators was collected from published

and unpublished historical literature and recent studies on stream conditions within various Estuary watersheds. Observations and data collected during field study of Estuary streams during the periods 1980-1981 and 1992-2004 also were used to supplement other information sources (Leidy 1984, Leidy 2004). We assumed that if a stream currently supported habitat suitable for coho salmon during the period 1980-2004 that it likely did historically as well.

RESULTS

We found definite evidence that at least 4 of the 65 (6%) Estuary watersheds that we assessed historically supported coho salmon (Table 1). An additional 11 watersheds (17%) also may also have supported coho salmon, but the evidence was inconclusive. Coho salmon were last documented from an Estuary stream in the early-to-mid 1980s. Collections of coho salmon from the open tidal-waters of the Estuary remain rare, supporting the conclusion that the species has been extirpated from the interior portions of its range in the Central Valley (Baxter et al. 1999, Moyle 2002, Leidy 2004).

We found only one record for the planting of hatchery-reared coho salmon into an Estuary stream during the 18th or 19th centuries. In 1960, fingerling coho salmon from the CDFG hatchery in Yountville were planted in Mill Valley Creek (Arroyo Corte Madera del Presidio), Marin County (CDFG files, Yountville Fish Base, Yountville). We located several records for the planting of hatchery-reared sub-catchable and catchable coho salmon into Estuary reservoirs during the 1970s, including: Arroyo del Valle Reservoir and Lake Elizabeth, Alameda County; San Pablo Reservoir, Contra Costa County; and Lake Merced, San Francisco County (CDFG files, Yountville Fish Base). Finally, during the 1970s-1980s the San Francisco Tyee Club reared and released hatchery coho salmon into San Francisco Bay near Tiburon (CDFG files, Yountville Fish Base).

Environmental Characteristics of Coho Salmon Streams

Coho salmon were geographically widespread in the Estuary, with evidence of occurrence within watersheds that drain at least seven ecological subsections (Table 2). The environmental characteristics of streams known historically to contain coho salmon, however, shared several environmental characteristics. Riparian communities were characterized typically by California bay, *Umbellularia californica*, coast redwood, *Sequoia sempervirens*, white alder, *Alnus rhombifolia*, and various species of willow, *Salix* spp. The coast redwood community was found in 8 of 15 watersheds (53%) with some evidence for the occurrence of coho salmon (Table 2). In addition, cool summer water temperatures, suitable spawning and juvenile rearing habitat, low stream gradients (< 3%), distinct surface water connections to the estuarine and marine environments, as well as stream flows during the months of February through May sufficient for smolt out-migration characterized all streams known or suspected historically to support coho salmon (Table 2).

Coho salmon typically were members of three-to-six species fish assemblages

Table 2. Selected environmental characteristics of streams with historical evidence for the occurrence of coho salmon within the San Francisco Estuary, California.

Watershed/ County/area km²	Ecological subsection[1]	Mean annual precipitation[1] (range cm)	Environmental indicators?[2]	Probable location of suitable spawning and rearing habitat	Current dominant riparian tree species[3]	Associated fish species[3]
(1) Walnut-Pine/ Contra Costa/474	East Bay Hills-Mt. Diablo	61-64	yes	Upper Pine Ck., Little Pine Ck., Arroyo del Cero Ck., San Cantanio (Sans Criante), Bollinger Canyon Ck.	mixed-willow, white alder, California bay, coast live oak	Pacific lamprey, California roach, steelhead, threespine stickleback
(2) San Pablo/ Contra Costa/113	East Bay Hills	51-64	yes	West Fork San Pablo Ck.,middle-to-upper San Pablo Ck.	mixed-willow, white alder, California bay, coast live oak	Pacific lamprey, California roach, Sacramento sucker (juvenile), steelhead, threespine stickleback, prickly sculpin
(3) Strawberry/ Alameda/5	East Bay Hills	64-71	yes	South Fork Strawberry Ck., upper mainstem Strawberry Creek	mixed-willow, white alder, California bay, coast live oak	steelhead, threespine stickleback

(4) Temescal Creek/	East Bay Hills	64-71	yes	Middle-to-upper mainstem Temescal Ck. bay, coast live oak	mixed-willow, white alder, California stickleback	steelhead, threespine
(5) San Leandro Creek/Alameda-Contra Costa/114	East Bay Hills	64-71	yes	Redwood Ck.,upper San Leandro Ck.,Indian Ck.	coast redwood, mixed-willow, white alder, California bay	Sacramento sucker (juvenile), steelhead, threespine stickleback, riffle sculpin? prickly sculpin
(6) San Lorenzo/ Alameda/124	East Bay Hills	64-71	yes	Crow Ck., Cull Ck., Palomares Ck., middle-to-upper mainstem San Lorenzo Ck.	mixed-willow, white alder, California bay, Fremont cottonwood, western sycamore	steelhead, California roach, Sacramento sucker (juvenile), threespine stickleback, prickly sculpin
(7) Alameda/ Alameda-Santa Clara/1,813	Fremont-Livermore Hills and Valleys Western Diablo Range	51-76	yes	Arroyo Hondo Ck., Calaveras Ck., Stoneybrook Ck., Sinbad Ck.?, Pirate Ck.?, Dry Ck.?, Alameda Ck.-Niles Canyon	mixed-willow, white alder, California bay, coast live oak, western sycamore	Pacific lamprey, California roach, Sacramento sucker (juvenile), steelhead, threespine stickleback, prickly sculpin

Table 2 (continued)

Watershed/ County/area km²	Ecological subsection[1]	Mean annual precipitation[1] (range cm)	Environmental indicators?[2]	Probable location of suitable spawning and rearing habitat	Current dominant riparian tree species[3]	Associated fish species[3]
(8) Coyote/ Santa Clara/917	Fremont-Livermore Hills and Valleys Western Diablo Range	51-76	yes	San Felipe Ck.,Upper Penitencia Ck.	mixed-willow, white alder, California bay, coast live oak, western sycamore	Pacific lamprey, California roach, Sacramento sucker (juvenile), steelhead, threespine stickleback, riffle sculpin
(9) Guadalupe/ Santa Clara/440	Santa Cruz Mtns.	76-152	yes	Upper reaches of: Los Gatos Ck., Guadalupe Ck.	California bay, coast live oak, coast redwood, Douglas fir, tanbark oak	Pacific lamprey, California roach, Sacramento sucker (juvenile), steelhead, riffle sculpin
(10) San Francisquito/ Santa Clara-San Mateo/109	Santa Cruz Mtns.	77-152	yes	Bear Ck.,West Union Ck., Corte Madera Ck., Los Trancos Ck.	coast redwood, California bay, white alder, coast live oak, mixed willow	California roach, Sacramento sucker (juvenile),

						steelhead, threespine stickleback, prickly sculpin
(11) San Mateo/ San Mateo/90	Santa Cruz Mtns.	51-127	yes	San Mateo Ck.	coast redwood, California bay, white alder, mixed willow	California roach, Sacramento sucker (juvenile), steelhead, threespine stickleback, riffle sculpin, prickly sculpin
(12) Arroyo Corte Madera del Presidio/Marin/21	Marin Hills and Valleys	76-152	yes	Arroyo Corte Madera del Presidio, Old Mill Ck., Cascade Ck.	coast redwood, California bay, mixed willow	California roach, steelhead, threespine stickleback, prickly sculpin, tidewater goby
(13) Corte Madera/ Marin/73	Marin Hills and Valleys	76-152	yes	Corte Madera Ck., Tamalpais Ck., Ross Ck., Sleepy Hollow Ck., San Anselmo Ck., Fairfax Ck., Cascade Ck.	coast redwood, California bay, white alder, mixed willow	Pacific lamprey, California roach, Sacramento sucker (juvenile), steelhead,

Table 2 (continued)

Watershed/ County/area km²	Ecological subsection[1]	Mean annual precipitation[1] (range cm)	Environmental indicators?[2]	Probable location of suitable spawning and rearing habitat	Current dominant riparian tree species[3]	Associated fish species[3]
						threespine stickleback, riffle sculpin, prickly sculpin, tidewater goby
(14) Sonoma/ Sonoma/440	Mt. St. Helena Flows and Valleys	76-152	yes	Upper Sonoma Ck., Bear Ck., All other tributaries with sufficient March-May flows	coast redwood, Douglas fir, tanbark oak, mixed oak, white alder, California bay	Pacific lamprey, California roach, Sacramento sucker (juvenile), steelhead, threespine stickleback, riffle sculpin
(15) Napa/ Napa/1,103	Mt. St. Helena Flows and Valleys	76-152	yes	Kimball Canyon Ck All other tributaries with sufficient March-May flows	coast redwood, Douglas fir, tanbark oak, mixed oak, white alder, California bay	Pacific lamprey, California roach, Sacramento sucker (juvenile), steelhead,

| | | |

depending on the specific watershed (Table 2). Coho salmon likely always occurred in streams supporting steelhead and Pacific lamprey, two species regularly associated with coho salmon in coastal Pacific drainages (Moyle 2002, Leidy 2004). Other fishes typically associated with coho salmon included California roach, juvenile Sacramento sucker, threespine stickleback, riffle sculpin, and prickly sculpin. In Arroyo Corte Madera del Presidio and Corte Madera creeks, Marin County, coho salmon occurred in the middle-to-lowermost reaches of streams with California roach, Sacramento sucker, threespine stickleback, riffle sculpin, prickly sculpin, and tidewater goby (Fry 1936, Leidy 2004). In the headwater reaches of streams, juvenile coho salmon likely were found with Sacramento sucker and steelhead that also used these streams reaches for spawning and rearing.

General Historical Distribution Patterns

Professor Alexander Agassiz from Harvard University and his associates collected fish from several Estuary streams during the 1850s and 1860s (Leidy 2004). Agassiz's collections from the Estuary are some of the earliest known collections of stream fishes from California, occurring prior to extensive hydrologic modification of Estuary streams. His collection of coho salmon from San Mateo Creek, San Mateo County, in 1860, is the earliest known record of this species for an Estuary watershed, and likely the Sacramento-San Joaquin Fish Province as well (refer to discussion of individual watersheds, below).

Snyder (1905) provided one of the first published descriptions of stream fish communities in the Estuary. Although Snyder described 13 fish species, including rainbow trout, as occurring in streams flowing into San Francisco Bay, he did not note the presence of coho salmon. Interestingly, Snyder (1908) also did not document the presence of coho salmon (or other salmonids) in coastal streams of Oregon and northern California; even though coho salmon were known to commonly occur during this time in many coastal streams of the region (i.e., Klamath and Russian rivers). Apparently, the omission of salmonids from early descriptions of species distributions was not unusual during this period, as Rutter (1908) failed to list Chinook salmon as occurring in the Sacramento and San Joaquin rivers even though spawning runs numbered in the hundreds of thousands of fish (Yoshiyama et al. 2001). Snyder's specific omission of coho salmon from streams tributary to San Francisco Bay may reflect more on such factors as sampling effort and timing (i.e., collections made during summer months when migrating adult fish are absent from streams), as well as his focus presumably on variation in non-salmonid species, rather than the absence of coho salmon from particular streams in the region.

Skinner (1962) discussed the distribution and ecology of coho salmon in his extensive review of fish and wildlife resources of the San Francisco Bay area. Skinner (1962: 66) states "In the Bay Area, silver salmon occur in most of the creeks directly tributary to the Pacific Ocean and at least a few streams tributary to San Francisco Bay." There is no mention in the text of the report of which specific streams tributary to San

Francisco Bay support coho salmon. However, Skinner (1962) does contain two maps (Plates IV and VI) depicting historical salmonid migration routes and probable distributions, as well as the present (circa 1962) distribution of salmonids within the San Francisco Bay, respectively. Specifically, the legend for Plate IV contains a heading for "Silver salmon and/or steelhead – Probable historical distribution" (Table X). Unfortunately, the maps do not differentiate between the distributions of coho salmon and steelhead where they both occur in the same stream. Presumably, a stream could contain only steelhead. Thus, one can assume only that some of the streams depicted on the maps supported coho salmon. In addition, Skinner (1962) does not provide the source(s) used to draw salmonid distributions on the maps. Finally, Skinner (1962) does not include several streams that were known to support coho salmon based in part on information developed by the CDFG (i.e., Arroyo Corte Madera del Presidio and Corte Madera creeks, Marin County). Notwithstanding these omissions, Skinner (1962) does confirm that some tributaries to the Estuary supported coho salmon at least until the early 1960s. We found corroborating evidence supporting the definite, probable, or possible occurrence of coho salmon for six of the twelve watersheds depicted by Skinner as supporting coho salmon or steelhead (Table 1).

Between 1875 and 1980, there are several records for the occurrence of juvenile and adult coho salmon in the surface waters of San Francisco and San Pablo bays (Leidy 2004). Presumably, adult coho salmon could be strays from Pacific coastal populations or fish migrating into Estuary watersheds or the Sacramento River system to spawn. The origin of juvenile coho salmon taken from the surface waters of the Estuary is not clear, but may represent locally spawned fish. From 1980-1995, only a single coho salmon was collected by midwater trawl in 1980 in San Pablo Bay (Baxter et al. 1999).

Brown et al. (1994) conclude that it is likely that prior to extensive hydrologic modifications, the Sacramento River system supported populations of coho salmon. We agree with the conclusions of Brown and Moyle (1991) and Bryant (1994) that presence of coho salmon in more inland locations in the Sacramento River system suggests that suitable habitats in Estuary streams that are geographically closer to the center of the species range likely also contained coho salmon.

Historical Distribution By Watershed

Walnut Creek, Contra Costa County. Gobalet et al. (2004) identifies coho salmon from an archaeological site on Walnut Creek, concluding that the fish probably were captured by Native Americans from within the drainage (Table 1). It is possible that the coho salmon were originally captured in San Francisco Bay and transported to the site adjacent to Walnut Creek. We agree with Gobalet et al (2004) that a likely source of these fish was Walnut Creek based on the likely historical presence of habitat suitable for coho salmon in the watershed (refer to discussion that follows).

Leidy (1983) mentioned anecdotal accounts by local residents of spawning migrations of coho salmon, as well as steelhead, in streams of the Walnut Creek watershed during the 1950s to mid-1960s (Table 1). Additional anecdotal evidence reported by the CDFG

also suggested that coho salmon were common in upper Pine Creek, a tributary to lower Walnut Creek, in the 1950s, but became rare in the late-1960s (CDFG[2] 1977). Little Pine Creek flows from the northwest slopes of Mt. Diablo approximately 3 miles to the confluence with Pine Creek. The CDFG[3] (1977) concluded that little Pine Creek provided fair to excellent steelhead and coho salmon habitat, but its potential was limited due to downstream urbanization and associated habitat alterations to Pine and Walnut creeks.

Arroyo del Cerro Creek also flows from the north slope of Mt. Diablo to join Pine Creek in the City of Walnut Creek. The CDFG[3] (1977) reported that despite its history as a steelhead and coho salmon stream, it did not appear to support an anadromous fishery at the time of the survey. This was due primarily to downstream migration barriers, loss of riparian vegetation, and water diversions and pumping. Some suitable spawning and rearing habitat for coho salmon currently remains in the upper Pine Creek watershed, including habitat in Upper Pine, Little Pine, and Arroyo del Cerro creeks.

Other streams in the Walnut-Ramon Creek watershed that historically may have supported coho salmon based on the presence of suitable habitat include San Cantanio (Sans Criante) and Bollinger Canyon creeks, two headwater tributaries to upper San Ramon Creek (Table 2). Downstream drop structures and culverts have blocked access to potential steelhead and coho salmon spawning and rearing habitat in both tributaries. These streams also have been degraded by flood control activities and adjacent land uses, such as grazing and suburban development. However, remnant reaches with well-shaded pools with cool water temperatures and complex instream cover suggest that under pre-disturbance conditions, these streams provided habitat for steelhead and perhaps coho salmon (Leidy 2004). Channelization for flood control of the lower-most reaches of mainstem Walnut Creek and its major tributaries has almost entirely blocked upstream anadromous salmonid migration routes to suitable spawning and rearing habitat. In addition, urbanization has significantly degraded potentially suitable habitat for coho salmon throughout the watershed. We rate the historical occurrence of coho salmon in the Walnut Creek watershed as probable.

San Pablo Creek, Contra Costa County. Gobalet (1990, 1994) documents the presence of either Chinook salmon or coho salmon from five archeological sites in the vicinity of lower San Pablo Creek. Middens date from the Middle horizon period (1,000 B.C. to A.D. 500). Unfortunately, species identification was not possible and, therefore, although the majority of the fish remains are likely Chinook salmon captured by boat from San Pablo Bay, some of the remains could be coho salmon captured from San Pablo Creek during spawning migrations (Gobalet et al. 2004).

We found a single published reference stating that coho salmon occurred in the San Pablo Creek watershed (Table 1). In their classic study of population variation in rainbow trout in coastal California and Mexico, Paul Needham and Richard Gard (1959: 40) noted that "Formerly it [i.e., San Leandro Creek, Alameda and Contra Costa

[2]California Department of Fish and Game (CDFG). 1977. River and stream survey files, Pine Creek, upper reach, Contra Costa County, 16 August 1977, Region 3, Yountville, California, 2 p. + map.

[3]CDFG. 1977. River and stream survey files, Arroyo del Cerro, Contra Costa County, 16-17 August 1977, Region 3, Yountville, California, 2 p. + map.

counties] flowed into San Francisco Bay near the City of Alameda and, like nearby San Pablo Creek, originally had runs of both steelhead and silver salmon" (Evans[1] 1957). While Evans' letter never specifically mentions the occurrence of coho salmon in San Pablo Creek, both Needham and Gard were intimately familiar with fishes in San Pablo Creek as a result of extensive fish sampling for research purposes and during annual field sampling trips for Needham's ichthyology class from the University of California, Berkeley. In addition to the above published reference, an avid salmon angler and longtime resident of the City of El Sobrante told the senior author of catching steelhead and coho salmon in San Pablo Creek downstream from San Pablo Dam in the late-1940s and early 1950s (C. Leggett, local resident, personal communication). We do not consider the above accounts as direct evidence and, therefore, have classified the occurrence of coho salmon in San Pablo Creek as probable (Table 1).

Construction of San Pablo Dam in 1918 blocked migration of anadromous salmonids into the upper San Pablo Creek watershed. Historically, the west fork of San Pablo Creek likely would have provided the highest quality spawning and rearing habitat for coho salmon in the upper watershed. The west fork of San Pablo Creek rises in the Oakland-Berkeley Hills and flows east from near the Broadway Tunnel (State Highway 24) for about 2 miles before joining the south fork of San Pablo Creek in the town of Orinda. Today the West Fork is entirely buried under Highway 24, except for a short reach in the uppermost headwaters. Needham and Gard (1959, p. 38-39) observed, "The west fork of San Pablo Creek is a lovely, clean little stream that never dries up in late summer. The quantity of water may fall to only a few gallons a minute, but since the stream is well shaded by trees or passes through tunnels over much of its course, water temperatures seldom get over 70° F [21° C] or approach the upper limits of tolerance for rainbows.... Many cut banks, rocks, boulders, and sunken logs or stumps provide excellent escape shelter. Alders, green bay, and buckeyes shade the stream almost completely over its course."

Zones of groundwater discharge along the Hayward Fault zone that traverses the west fork would have maintained cool summer water temperatures. These zones of groundwater discharge are observable today in remnant reaches of the upper headwaters of the west fork (Leidy 2004). During August of 2002, we recorded water temperatures within several small, well-shaded pools along the upper west fork at between 14.4-17.8° C. Summer water temperatures suitable for rearing coho salmon were likely present historically in the west fork.

Suitable rearing habitat for coho salmon likely was also present historically downstream of San Pablo Dam near the City of El Sobrante, based on my observations of this reach during 1981 and 1999. During fish surveys the senior author observed groundwater seeping from the streambanks of San Pablo Creek throughout this reach. Mid-afternoon water temperatures in pools within these zones of groundwater discharge ranged from 13.9-17.2° C in July 1981, a drought year, to 13.5-14.4° C during late-April

[1]Evans, W.A. 1957. River and stream survey files, San Leandro Creek, Alameda County. Unpublished letter from W.A. Evans, CDFG, to P.R. Needham, U.C. Berkeley, 21 February/1957, CDFG, Region 3, Yountville, California 1 p.

1999, a year of above-average precipitation. In addition, this reach is currently characterized by complex instream cover in the form of undercut banks and large coarse woody debris (i.e., logs and branches), as well as nearly complete riparian canopy closure. Cool water temperatures are present even in the absence of minimum flow releases from San Pablo Dam. Our observations of habitat conditions in the 1980s-1990s suggest that historically, prior to the construction of San Pablo Dam, much of San Pablo Creek from El Sobrante upstream likely would have contained adequate spawning and rearing habitat for coho salmon.

During April 1974, a single juvenile (38 mm fork length) coho salmon was collected by otter trawl over mudflat in San Pablo Bay in the vicinity of San Pablo Creek marsh and Richmond Sanitary Landfill (Nakaji 1975). The origin of a juvenile coho salmon at this location in the Bay-Estuary is not clear, but suggests that this fish may have been spawned in a nearby stream and subsequently washed or moved downstream.

Strawberry Creek, Alameda County. Gobalet et al. (2004) references the identification of coho salmon remains from an archaeological site near Strawberry Creek by Follett (1975), and concludes that the fish could have been captured during spawning runs from the creek. Follett (1975) concludes that the coho salmon may have been taken either in nearby San Francisco Bay or in Strawberry Creek.

A July 1939 memorandum documents that W. I. Follett, Curator Emeritus of Ichthyology for the California Academy of Sciences, and also an Oakland resident, informed L. Shapovalov of the California Division of Fish and Game that Strawberry Creek "had supported a run of Silver [coho] Salmon." We consider this record very reliable given the source; however, it is likely not based on direct observation by Follett (Shapovalov[5] 1939: 1). Charbonneau and Resh (1992: 298) note that, "Steelhead salmon (*Oncorhynchus kisutch*)" were last noted during spawning migrations on the U.C. Berkeley Campus in the early 1930s. The somewhat confusing reference by Charbonneau and Resh (1992: 298) to "Steelhead salmon" may refer to steelhead, *Oncorhynchus mykiss*, rather than coho salmon. Steelhead are known to occur in all streams where coho salmon were known to occur in the Estuary, so their co-occurrence in Strawberry Creek cannot be ruled out, especially given the California Division of Fish and Game reference during the same period.

The headwaters of Strawberry Creek are crossed by the Hayward fault near the base of the Oakland-Berkeley Hills. Faulting has contributed to the formation of numerous groundwater seeps along the headwater reaches of the North and South Forks of Strawberry Creek. These seeps maintain permanent, cool water habitat in the headwaters, and presumably provided suitable rearing habitat for coho salmon and steelhead trout prior to degradation of the creek beginning in the 1880s (Charbonneau and Resh 1992). The South Fork in Strawberry Canyon still supports remnant stream reaches that contain cool, small, well-shaded pools and we believe that the stream likely contained suitable habitat for coho salmon historically (Leidy 2004, Table 2). In the absence of direct evidence, we consider the historical occurrence of coho salmon in Strawberry

[5]Shapovalov, L. 1939. River and stream survey files, Strawberry Creek, Alameda County, supplementary sheet, CDFG, Region 3, Yountville, California, 1 p.

Creek as probable (Table 1).

Temescal Creek, Alameda County. Fish remains belonging to coho salmon were identified from an archaeological site near Temescal Creek (Broughton 1997, Gobalet et al. 2004). Gobalet et al. (2004) concludes that the coho salmon may have been taken by Native Americans from Temescal Creek. Follett (1975) cites the historical accounts of others (see Louderback 1940, Schenck 1926) of "salmon" in Temescal Creek to suggest that habitat suitable for coho salmon may have been present in Temescal and Strawberry creeks, although the accounts may refer to either steelhead or coho salmon.

Historically, the upper reaches of Temescal Creek likely supported habitat suitable for coho salmon (Table 2). However, in the absence of conclusive direct evidence, we consider the historical occurrence of coho salmon in Temescal Creek as probable.

San Leandro Creek, Alameda and Contra Costa Counties. We found only one reference to coho salmon in the San Leandro Creek watershed. As noted above in the discussion of San Pablo Creek, California Division of Fish and Game Warden George Smalley reported runs of coho salmon and steelhead in San Leandro Creek "...in the early days" and "...that after the completion of the Upper San Leandro Reservoir a run still persisted to the base of the dam for many years" (Evans[1] 1957). However, it is not clear whether the reference is based on direct observation or a second-hand account.

The status of coho salmon in San Leandro Creek is confused by early historical accounts of several species of the genus *Oncorhynchus* from the watershed. There are references in the 1870s for the occurrence of "quinnant" or Chinook salmon in lower San Leandro Creek and Lake Chabot (U.S. Commission on Fish and Fisheries 1877, California Commissioners of Fisheries 1878). Chinook salmon purportedly maintained populations for several years following the construction of Lake Chabot in 1875 (California Commissioners of Fisheries 1878). Unlike coho salmon, Chinook salmon are occasionally known to establish viable reservoir populations in California and elsewhere, and there is the remote possibility that populations of Chinook salmon temporarily became established in the lake by fish trapped above the dam. Chinook salmon may have established temporary populations in San Andreas Reservoir after its completion in 1870, as well (Stone 1873, refer to San Mateo Creek discussion, below).

Landlocked steelhead are known to maintain viable populations in Chabot Reservoir and several tributary streams (Gall et al. 1990). In addition, Lake Chabot was stocked irregularly in the 1870s and 1880s with "schoodic" or the landlocked form of Atlantic salmon, *Salmo salar*, originally from Maine (Leidy 2004). The above circumstances raise the possibility of misidentification of the various species of *Oncorhynchus* and *Salmo* in the San Leandro Creek watershed. We consider the California Division of Fish and Game record for the historical occurrence of coho salmon in San Leandro Creek reliable, especially since we believe that suitable habitat was present in the watershed. The validity of records for historical presence of Chinook salmon is strengthened by the fact that individuals presumably competent to identify salmon worked at the State-hatching house at Lake Chabot. Therefore, San Leandro Creek may have historically supported two or possibly three species of *Oncorhynchus*. It is also possible that only steelhead were present in the watershed.

Headwater tributaries of San Leandro Creek, particularly San Leandro, Redwood,

and Indian creeks, lie within the well-shaded, narrow canyons of the Oakland Hills that are dominated by the coast redwood-bay laurel riparian communities. Geologically, this portion of the East Bay Hills is intensively folded and faulted and the headwater streams contain perennial pools maintained by groundwater seeps. Stream gradients are typically < 3 %. The tributaries currently function as spawning and rearing habitat for landlocked steelhead that migrate out of Upper San Leandro Reservoir. Historically, San Leandro Creek from the present site of Lake Chabot upstream would have likely served as spawning and rearing habitat for coho salmon. Because of the lack of direct evidence, we consider the occurrence of coho salmon in San Leandro Creek as probable.

San Lorenzo Creek, Alameda County. Skinner (1962, Plate IV) identified San Lorenzo, Crow, Cull, and Palomares creeks as probable historical migration routes and habitat for silver salmon and/or steelhead prior to 1962. Skinner (1962, Plate VI) also identified San Lorenzo, Crow, and Cull creeks as "lightly used streams" by steelhead and/or coho salmon in circa 1962, but again did not identify which streams, if any, were used by coho salmon. Landowners also have reported coho salmon in Crow Creek during the 1960s (Alameda County Flood Control and Water Conservation District and Hagar Environmental Services 2002).

Early-19th Century Euro-Americans described the mainstem of San Lorenzo Creek as a perennial stream fed by springs and characterized by a well-developed riparian canopy of willows throughout its length (Grossinger and Brewster 2003). Historical photographs of the middle-mainstem reaches depict a low-gradient (<3%), well-shaded, stream with a gravel-cobble substrate (Grossinger and Brewster 2003). Urbanization has eliminated suitable habitat for coho salmon that may have existed historically within the San Lorenzo Creek watershed (Leidy 2004).

Alameda Creek, Alameda County. We classified the occurrence of coho salmon in Alameda Creek as definite. There is some anecdotal evidence that coho salmon were known to have occurred in Alameda Creek in the late-1930s (John Hopkirk, personal communication, 1981). Skinner (1962, Plate IV) identified Alameda, Calaveras, San Antonio, Indian, La Costa, Arroyo de la Laguna, Arroyo del Valle, Arroyo las Positas, and Arroyo Mocho creeks as probable historical migration routes and habitat for silver salmon and/or steelhead prior to 1962. Unfortunately, Skinner did not differentiate specific streams used by coho salmon, nor cite his information source. Skinner (1962, Plate VI) also identified Alameda, lower San Antonio, lower Arroyo de la Laguna, and lower Arroyo del Valle creeks as "lightly used streams" by steelhead and/or coho salmon in circa 1962, but again did not identify which streams, if any, were used by coho salmon.

Probably the most compelling evidence for the occurrence of coho salmon in the Alameda Creek watershed is photographic evidence during the 1940s to 1960s (Alameda Creek Alliance[6] 2002). An angler in Niles Canyon caught and photographed two adult coho salmon in February 1964 (Alameda Creek Alliance[6] 2002). An angler also

[6]Alameda Creek Alliance. 2002. Photographs taken of fish caught by (1) H. Janssen, February 11, 1964, along concrete wall on Old Pottery Road, and (2) R. Mills, circa 1940s-1950s, Alameda Creek watershed. From files of Alameda Creek Alliance, Canyon, California.

caught an adult coho salmon sometime during the 1940s to 1950s in Sinbad Creek, a tributary to Alameda Creek near the head of Niles Canyon (Alameda Creek Alliance[6] 2002). The date of the 1964 photograph suggests that the fish were on their spawning migration. That two adult fish were caught also indicates that they may have been part of a larger spawning migration, although their occurrence as strays cannot be ruled out.

The most likely location of historically suitable habitat for coho salmon was in the small, perennial tributaries to Alameda Creek (i.e., Dry, Stoneybrook, Pirate), mainstem Alameda Creek at Little Yosemite, headwaters to San Antonio Creek (i.e., La Costa and Indian creeks), and Calaveras Creek, and its primary tributary Arroyo Hondo Creek, below migration barriers. Construction of Calaveras and San Antonio reservoirs in 1925 and 1964, respectively, would have destroyed and isolated significant reaches of potentially suitable coho salmon habitat. Augmentation of summer flows in the Niles Canyon reach of Alameda Creek beginning in the 1920s may have artificially improved habitat for coho salmon during spring and summer months. However, the operation of instream percolation dams for groundwater recharge in Alameda Creek downstream from Niles Canyon likely would have blocked out-migrating coho salmon smolts.

Coyote Creek, Santa Clara County. We are aware of only a single reference to the occurrence of coho salmon in the Coyote Creek watershed. Apparently coho salmon may have been present in Coyote Creek into the 1950s prior to the completion of Anderson Dam (L. J. Hendricks, Emeritus, San Jose State University, personal communication, as cited in Smith 1998). The apparent persistence of coho salmon in the watershed into the 1950s suggests that some spawning and rearing habitat was located in the watershed downstream from Coyote Reservoir that was completed in 1936 and blocked access to about 310 km^2 of the watershed upstream from the reservoir. Whether the Coyote Percolation Reservoir constructed in 1934 on lower Coyote Creek below the present site of Anderson Reservoir was a complete barrier to migrating salmon is not known.

Historically, suitable habitat for coho salmon in the Coyote Creek watershed was likely restricted to the San Felipe Creek and Upper Penitencia Creek watersheds and possibly perennial reaches of Coyote Creek, and a few spring-fed tributaries upstream from Gilroy Hot Springs. Assuming the Coyote Percolation Reservoir was not a complete barrier to coho salmon: the construction of Anderson Dam would have eliminated any coho salmon that occurred in the San Felipe Creek watershed that now flows into Anderson Reservoir. However, if the Coyote Creek Percolation Reservoir were a migration barrier, then only Upper Penitencia Creek would have provided suitable habitat for coho salmon after 1934.

We believe that San Felipe Creek currently contains habitat potentially suitable to coho salmon (Leidy 2004). During early June and late-July 1997, the senior author recorded water temperatures within the San Felipe Creek watershed within pools containing rainbow trout between 11-13.3° C and 14.4-17.7° C, respectively. Zones of groundwater discharge along the Calaveras Fault zone that traverses the watershed maintain cool summer water temperatures.

Upper Penitencia Creek, which enters lower Coyote Creek near its mouth and drains the steep coastal hills to the east also may have contained suitable coho salmon habitat.

The upper watershed within Alum Rock Park contains habitat potentially suitable for coho salmon, although natural cascades and waterfalls block the additional suitable habitat in the uppermost reaches of Upper Penitencia Creek and its major tributary, Arroyo Aguague Creek (Leidy 2004).

Guadalupe River-Los Gatos Creek, Santa Clara County. Coho salmon are listed as historically occurring in the Guadalupe River (Santa Clara Basin Water Management Initiative 2001, Guadalupe-Coyote Resource Conservation District[7] 2001, L. Johmann[8,9] 2002). The evidence is based on observations of coho salmon in the Guadalupe River system by longtime local residents and anglers, made mostly between the 1920s to 1960s (Johmann[8,9] 2002). We believe that the Guadalupe River watershed possibly supported coho salmon based on multiple historical accounts of "salmon" utilizing the stream; some from individuals qualified to identify salmon, and based on the presence of suitable habitat conditions.

Based largely on the locations of fish collections made in 1895 by Snyder (1905), Smith (1999) concluded that historically the Guadalupe River and Los Gatos Creek likely supported heavy steelhead use throughout. Smith (1999: 3) observed for lowland reaches that, "Based on historical fish records, it seems likely that most of the channel on the two streams [i.e., Guadalupe River and Los Gatos Creek] was originally narrow and well-shaded and often provided cool water summer habitat suitable for heavy steelhead use." Cool summer water temperatures and a narrow, well-shaded channel are conditions that also would be favored by coho salmon.

The upper watersheds of the Guadalupe River, Los Gatos, and Alamitos creeks lie within zones of high precipitation and movement along the San Andreas Fault has created extensive zones of groundwater discharge. These streams currently contain habitat conditions suitable for coho salmon spawning and rearing; however, several large dams now block these stream reaches. The construction of several reservoirs, including Williams Reservoir (1895), Vasona Percolation Reservoir (1935), Austrian Dam-Lake Elsman (1950), and Lexington Reservoir (1953) blocked high quality coho salmon spawning and rearing habitat and altered flow regimes on Los Gatos Creek and several tributaries. On Guadalupe Creek, Guadalupe Dam was completed in 1935, blocking coho salmon access to Guadalupe and Los Capitancillos creeks. Access to potentially suitable habitat on Alamitos Creek and two tributaries, Herbert Creek and Barrett Canyon, was blocked with the construction of Almaden Reservoir in 1936. Anecdotal accounts, historical conditions in the lower watershed, and current habitat conditions in the upper watershed argue for the possible occurrence of coho salmon

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[7]Guadalupe-Coyote Resource Conservation District. 2001. Historic salmonid references. Available at 888 North First Street, Rm. 204, San Jose, California 95112. http://www.gcred@pacbell.net.

[8]Johmann, L.M. 2002. Documented accountings of salmonids in south bay waters. Unpublished report, 4 pp.

[9]Johmann, L.M. 2002. Reported accountings of salmonids in south bay waters. Unpublished report, 4 pp.

in the Guadalupe River watershed.

San Francisquito Creek, Santa Clara and San Mateo Counties. Gobalet et al. (2004) notes that the unidentified remains of salmonids from an archaeological site near San Francisquito Creek are possibly from coho salmon. Whether the coho salmon were captured by Native Americans in San Francisquito Creek or from nearby San Francisco Bay is unknown.

As in the Guadalupe River watershed, coho salmon are listed as historically occurring in San Francisquito Creek (Santa Clara Basin Water Management Initiative 2001, Guadalupe-Coyote Resource Conservation District 2001, L. Johnann, personal communication). Local residents and anglers reported the presence of coho salmon in the watershed.

There is evidence that San Francisquito Creek was characterized by perennial flow to the Bay-Estuary until the early 1900s. The most likely location of historically suitable habitat for coho salmon was in perennial, well shaded reaches of mainstem San Francisquito Creek, and several small, perennial tributaries including Los Trancos, Corte Madera, Bear, and West Union creeks. These streams rise in the coast-redwoods of the Santa Cruz Mountains along the traverse of the San Andreas Fault Zone. Construction of Searsville Lake on San Francisquito Creek in 1890 blocked access to Corte Madera Creek and its tributaries. There is extensive groundwater pumping in the watershed by local residents that likely has severely reduced summer base flows and salmonid rearing habitat.

San Mateo Creek, San Mateo County. In 1860, Alexander Agassiz collected eight coho salmon from San Mateo Creek, San Mateo County (Museum of Comparative Zoology[10] 1860). The collection was prior to the construction of San Andreas and Lower Crystal Springs reservoirs on upper San Mateo Creek, in 1870 and 1888, respectively, which blocked fish access into much of the upper watershed. Presumably, some of the highest quality spawning and rearing habitat for coho salmon occurred within, and upstream from, the site of the reservoirs where riparian forests would largely have been dominated by coast redwood, California bay, mixed willow, and white alder. Upper San Mateo Creek runs directly along the San Andreas Rift Zone, characterized by extensive groundwater discharge. Interestingly, Agassiz's specimens of coho salmon were originally collected with rainbow trout and California roach (Museum of Comparative Zoology[11] 1860). The latter two species are often found together along with either riffle sculpin or prickly sculpin in the headwater reaches of Estuary streams (Leidy 1984).

There are early references to the likely occurrence of either Chinook and/or coho salmon in San Andreas Lake and Crystal Springs reservoirs, although the identification and source of the fish is not clear. In a review of hunting and fishing within San Francisco County, Hallock (1877: 15) notes that "...San Andreas [Reservoir is filled], chiefly with silver salmon of generally moderate size." Stone (1873: 201) describes

[10]Museum of Comparative Zoology, Harvard, ichthyology collection nos. MCZ 7123: 4 and MCZ 68471: 4. Cambridge, Massachusetts.

[11]Museum of Comparative Zoology, Harvard, ichthyology collection nos. MCZ 7083: 24, MCZ 52008: 39, and MCZ 1971: 21. Cambridge, Massachusetts.

juvenile and adult *Oncorhynchus* from "San Andrea's [San Andreas] lower reservoir" that may also be coho or Chinook salmon based on his description of morphology and coloration. Stone (1873: 201) describes the fish as "silvery" or "silver trout" with "no colored spots," observing that the fish "very much resembles [a] salmon smolt." The timing of the observations of *Oncorhynchus* within the reservoirs is consistent with an explanation that the fish were trapped following the initial damming of San Mateo Creek to form San Andreas Reservoir in 1870. Chinook salmon are known to persist in reservoirs and their tributaries, as apparently was the case in Chabot Lake in Alameda County following the damming of San Leandro Creek (see discussion, above). It is also possible that the fish described by Hallock and Stone were anadromous or "landlocked" steelhead trapped in the reservoir. Landlocked steelhead are known to grow to large size and attain a silvery coloration in other reservoirs in the Estuary, where they migrate into tributary streams to spawn (Leidy 2004).

Arroyo Corte Madera del Presidio, Marin County. Shapovalov (1946: 3-4) observed, "It is possible that in past years, and perhaps even recent times, Silver Salmon have also utilized these streams [*i.e.*, Arroyo Corte Madera del Presidio and Old Mill Creek] for spawning purposes." Shapovalov[12] (1946) recommends the stocking of coho salmon in the watershed, based on his finding that suitable spawning and nursery habitat for this species existed in the watershed at the time of his survey in 1946. Hallock and Fry (1967: 15) noted that coho salmon rarely occurred in the Sacramento-San Joaquin system, "although there were and perhaps still are spawning runs in a least two small Marin County streams tributary to San Francisco Bay. These are Corte Madera Creek and Arroyo Corte Madera Del Presidio. The latter is often called Mill Valley Creek."

There is a 1946 reference to the use of Old Mill Creek, a tributary to Arroyo Corte Madera del Presidio, by "sea-run steelhead and other salmonids" (Shapovalov[12] 1946: 2). We located a 1960 CDFG record for the stocking of 2,080 coho salmon fingerlings into Mill Valley Creek (CDFG, Silverado Fish Base files, Yountville, California, 17 June 1960). There is also a 1963 reference for Arroyo Corte Madera del Presidio Creek and its tributaries serving as "Important spawning and nursery area[s] for steelhead and possibly salmon" (CDFG[13] 1963: 1). These references are likely referring to the presence of coho salmon in these waters in addition to steelhead.

Leidy (1984) collected and released a total of two adults and five juvenile coho salmon from two sites on lower Arroyo Corte Madera del Presidio in 1981 (18 September 1981, 2: 176-197 fork length; 5: 56-101 fork length). The fish were collected from a small, well-shaded, shallow pool with a gravel-cobble substrate. The water temperature was 13.3° C. This collection and another on the same date in Corte Madera Creek are likely the last known records for coho salmon in the streams within the Estuary.

Arroyo Corte Madera del Presidio is perennial and is characterized by riparian

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[12]Shapovalov, L. 1946. River and stream survey files, Old Mill Creek, Marin County, field note, California Department of Fish and Game, Region 3, Yountville, California. 2 pp.

[13]CDFG. 1963. River and stream survey files, Arroyo Corte Madera del Presidio and tributaries, 16 July 1963, Region 3, Yountville, California. 3 pp.

communities dominated by coast redwood, California bay laurel, and several willow species. Water temperature and rearing habitat is suitable for coho salmon.

Corte Madera Creek, Marin County. Gobalet et al. (2004) notes that Follett (1957, 1974) identified remains from the genus *Oncorhynchus* from archaeological sites near Corte Madera Creek. These remains may be from steelhead, Chinook salmon, and/or coho salmon.

We found a 1926 record for the collection of 10 juvenile coho salmon at the "Mouth of San Rafael [Corte Madera] Cr" (California Academy of Sciences[14] 1926). In a study of the life history of California roach, Fry (1936) noted the occurrence of coho salmon in San Anselmo Creek, a tributary of Corte Madera Creek. Fry (1936) also described San Anselmo Creek as perennial with well shaded pools, complex instream cover in the form of woody debris, and long, relatively deep pools. Hallock and Fry (1967: 15) found that coho salmon rarely occurred in the Sacramento-San Joaquin system, "although there were and perhaps still are spawning runs in a least two small Marin County streams tributary to San Francisco Bay. These are Corte Madera Creek and Arroyo Corte Madera Del Presidio."

Coho salmon were observed in Fairfax Creek, a tributary to Corte Madera Creek, during their spawning runs as late as 1965 (Cronin[15] 1980). Coho salmon were thought to spawn historically upstream from the town of Fairfax (Cronin 1980[15]). Leidy (1984) collected and released coho salmon from lower Corte Madera Creek in 1981 (18 September 1981, 2: 64 mm fork length). The fish were collected from a relatively long, moderately deep, well-shaded pool with a gravel-cobble substrate. The water temperature was 14.4° C. In January 1986, fourteen adult coho salmon were observed in Corte Madera Creek, but these fish may have originated from a 1983 transplant of approximately 600 coho salmon fry from Lagunitas Creek, a nearby coastal Pacific drainage (Emig[16] 1986). Finally, Rich (2000, Table 1) documents several anecdotal records (i.e., "no written records found") for the occurrence of coho salmon in tributaries of Corte Madera Creek, including Ross, San Anselmo, Sleepy Hollow, Fairfax, and Cascade creeks. Suitable habitat for coho salmon is present in all these tributaries (Table 2).

Sonoma Creek, Sonoma County. Skinner (1962) notes the occurrence of coho salmon and/or steelhead in Sonoma Creek. Although the Sonoma Creek watershed supports a regionally significant run of steelhead, we were unable to locate any historical evidence for the occurrence of coho salmon within the watershed (Leidy et al. 2003). Recent studies indicate that habitat suitable for coho salmon may be present within several headwater tributaries of the Sonoma Creek watershed (Leidy 2004,

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[14]California Academy of Sciences. 1926. Fish collection, 18 Mar 1926, collected by E. C. Scofield, catalog no. SU 59662: 10. San Francisco, California.

[15]Cronin, L.T. 1980. Restoration of Corte Madera Creek. Letter from L.T. Cronin, California Council of Trout Unlimited, to the California Department of Water Resources, 29 November 1980. California Department of Fish and Game, Region 3, Yountville, California. 2 pp.

[16]Emig, J.W. 1986. River and stream survey files, Corte Madera Creek, Marin County, 24 January 1986. California Department of Fish and Game, Region 3, Yountville, California. 1 p.

Sonoma Ecology Center 2004).

Napa River, Napa County. The Napa River historically and currently supports the largest run of steelhead within the Estuary (Leidy et al. 2005). In a 1966 study, the U.S. Fish and Wildlife Service, in cooperation with the CDFG, estimated that the Napa River supported an annual run of approximately 4,000 adult coho salmon (U.S. Fish and Wildlife Service[17] 1968). This run has since been eliminated. Unfortunately, the 1966 report did not provide evidence in support of this run size estimate for coho salmon in the Napa River watershed. A single coho salmon was captured in the Napa River Marsh in 1982, but the origin of this fish was not known (Emig[18] 1983).

Suitable habitat for coho salmon within the Napa includes several tributary streams flowing east and west to the mainstem Napa River from the narrow, well-shaded canyons of the Sonoma, Mayacama, and Vaca ranges. Coast redwood-Douglas fir, white alder, and oak-tanoak riparian communities characterize the tributaries. Zones of groundwater discharge are common along fault zones on the headwater reaches of many of these streams.

DISCUSSION

Estuary streams display ecological conditions and fish assemblages transitional between north and central coastal Pacific and Central Valley watersheds (Leidy 2004). In addition to containing more saltwater dispersant fishes than the Central Valley, Estuary streams also support more freshwater dispersant fishes than Pacific coastal drainages. For some species such as coho salmon, under historical conditions there was a gradient of decreasing population abundance from coastal Pacific, to Estuary, and to Central Valley watersheds. In the Estuary, coho salmon utilized habitats characterized by environmental conditions similar to those more commonly found in the high-rainfall coastal streams directly tributary to the Pacific Ocean that historically had relatively high abundances of coho salmon.

Other than our assessment, no review of the historical distribution of coho salmon in Estuary watersheds considered distribution records in the context of essential habitat requirements. As a result, previous studies likely have underestimated use of Estuary watersheds by coho salmon historically (Leidy 1984, Brown *et al.* 1994, Weitkamp et al. 1995, Adams et al. 1999, NMFS 2001, CDFG 2002). We found definite evidence that at least four Estuary watersheds (6%) historically supported coho salmon, with some evidence for their probable occurrence in another six watersheds (9%). Thus, we conservatively estimate that between 6-15% of Estuary watersheds

[17]U.S. Fish and Wildlife Service. 1968. Analysis of fish habitat of Napa River and tributaries, Napa County, California, with emphasis given to steelhead trout production. File memorandum, dated October 21, 1968, U.S. Fish and Wildlife Service, River Basin Studies, Sacramento, California. 22 p.

[18]Emig, J. W. 1983. River and stream survey files, Napa River, Napa County, field note dated 15 December 1983. California Department of Fish and Game, Region 3, Yountville, California. 1 p.

likely supported coho salmon.

Coho salmon are known to stray between watersheds (Shapovalov and Taft 1954, McElhany et al. 2000). However, coho salmon stray rates are highly variable, making generalizations about the magnitude of dispersal between watersheds difficult (McElhany et al. 2000). We were unable to make any generalizations about the origins of coho salmon spawners migrating into non-natal watersheds. Therefore, the possibility exists that some historical observations of single to a few coho salmon in Estuary watersheds cited in this study are the result of straying behavior in hatchery and/or wild spawners. Our review also indicates that the planting of coho salmon of hatchery origin in Estuary streams was likely extremely rare. This is not the case, however, for hatchery-reared steelhead, which received widespread and repeated plantings in Estuary watersheds.

Observations of coho salmon in a stream, especially migrating adult fish, also does not necessarily confirm the presence of a persistent population (B. Spence, NMFS, personal communication). As noted, adult coho salmon observed in a stream may be stray fish of hatchery origin rather than members of a persistent population. Because populations of coho salmon in Estuary streams are at the edge of their geographical range they may be relatively small and therefore, extremely vulnerable to localized extinctions (J. Smith, San Jose State University, personal communication).

Coho salmon showed a potentially broad geographic distribution in the Estuary, occurring in streams within seven ecological zones or subsections. This broad geographic distribution likely reflects the ability of coho salmon to adapt to local environmental conditions of their natal stream (CDFG 2002). Environmental characteristics of streams known historically to contain coho salmon shared several characteristics, most notably year-round cool water temperatures. Zones of groundwater discharge associated with faulting probably played an important role in maintaining suitable water temperatures for rearing coho salmon within the warmer, interior regions of the Estuary (e.g., Walnut, Alameda, and Coyote creeks). Coho salmon definitely occurred in three watersheds, and probably another two watersheds, characterized by the coast redwood riparian community, which is more typical of the high-rainfall coastal streams directly tributary to the Pacific Ocean that historically had relatively high abundances of coho salmon. All streams known or suspected to support coho salmon historically were characterized by distinct surface water connections to estuarine and marine environments, as well as stream flows during the months of February through May suitable for smolt out-migration.

CONCLUSIONS

Coho salmon populations have experienced declines throughout California attributable primarily to human activities, including water diversions, creation of migration barriers, streambed alteration for flood control, impaired water quality, removal of riparian vegetation, disruption of natural hydrological processes, and reduced instream habitat complexity (CDFG 2002). Physical changes to Estuary watersheds from urbanization have not only resulted in the extirpation of coho salmon

but have made the assessment of the historical suitability of streams difficult. Consequently, we believe existing status reviews likely have underestimated the historical use of Estuary streams by coho salmon. Our best estimate indicates that a minimum of approximately 6-15% of Estuary watersheds likely contained coho salmon historically. Recovery goals for coho salmon in California include reintroduction into suitable stream habitats (CDFG 2002). Recent efforts to prioritize streams for the restoration of coho salmon within the Central Coast ESU include two Estuary watersheds, Arroyo Corte Madera del Presidio and Corte Madera creeks, Marin County (CDFG 2002). We recommend that the potential for the reestablishment of coho salmon into other watersheds with suitable habitat conditions be explored, especially watersheds where seasonal flow releases from large reservoirs have the potential to restore instream flows within stream reaches that supported coho salmon in the past.

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GIANT GARTER SNAKE SURVEYS AT SOME AREAS OF HISTORIC OCCUPATION IN THE GRASSLAND ECOLOGICAL AREA, MERCED CO. AND MENDOTA WILDLIFE AREA, FRESNO CO., CALIFORNIA

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ABSTRACT

The Threatened (California and Federal listings) giant garter snake, *Thamnophis gigas*, is endemic to still and slow-moving waterways of California's Central Valley, such as sloughs, canals, and cattail and tule marshes. Giant garter snakes have experienced substantial habitat loss in the San Joaquin Valley and are seemingly no longer present in some sites where they were documented in the mid-1970's. In 2001 we conducted giant garter snake surveys on both publicly and privately owned lands in the Grassland Ecological Area and at the Volta Wildlife Area, both located in western Merced County, as well as at two sites in Fresno County; Mendota Wildlife Area and Alkali Sink Ecological Reserve. We performed visual surveys for giant garter snakes in early morning when basking snakes were most visible. In addition, at 18 study sites we set floating funnel traps for giant garter snakes along approximately 19 km of wetland edge. We did not encounter any giant garter snakes during our visual surveys. We trapped 15 giant garter snakes; 14 at the Mendota Wildlife Area and 1 in the southern Grassland Ecological Area. We recorded morphological measurements, physical characteristics, and implanted PIT tags into all captured giant garter snakes prior to release at the point of capture. We did not capture any juvenile giant garter snakes nor did we recapture any giant garter snakes; the snake that was captured in the southern Grassland Ecological Area was not a recapture although giant garter snakes were captured at this site in previous surveys. Giant garter snakes were definitively documented on the Mendota Wildlife Area in 2001, the first year since the mid-1970's. However, we have not found giant garter snakes at the Volta Wildlife Area since 1999, despite conducting surveys there in 2000 and 2001. The late summer timing of trapping efforts could explain this result. Giant garter snakes still persist in some San Joaquin Valley locations thus future research efforts should strive to understand their current status, distribution, and the threats to their continued survival. This basic information is needed to protect populations

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of giant garter snakes in the San Joaquin Valley through effective land management decision making on existing giant garter snake habitat and for the restoration of giant garter snake habitat in areas where it is currently absent or degraded.

INTRODUCTION

The giant garter snake, *Thamnophis gigas*, is endemic to the Central Valley of California. Historically, it ranged from near Gridley, Butte County, south to Buena Vista Lake near Bakersfield, Kern County (Hansen and Brode[2] 1980). The Tulare Lake Basin in the southern San Joaquin Valley once constituted a significant portion of giant garter snake habitat. Reclamation of the basin for agricultural purposes was possible upon completion of Pine Flat and Isabella dams on the Kings and Kern rivers, respectively, and thus the range of the giant garter snake was reduced by approximately one-third (Hansen and Brode[2] 1980).

Giant garter snakes are most often drab olive in color, some with black mottling dorsally. In contrast to giant garter snakes found in the Sacramento Valley, giant garter snakes in the San Joaquin Valley may not have any dorsal striping, although striped individuals do occur (Rossman et al. 1996). The snake has a long muzzle, with muzzle length to frontal length ratio averaging approximately 85% in males and approximately 95% in females (Rossman et al. 1996). The valley garter snake, *Thamnophis sirtalis fitchi*, also occurs in the San Joaquin Valley, but the valley garter snake can easily be differentiated from the giant garter snake due to the bright red spots along its lower dorsolateral area (Stebbins 2003). The giant garter snake has 8 supralabials, with the 7th wider than the 6th, as opposed to generally 7 supralabials in valley garter snakes (Rossman et al. 1996). Adult giant garter snakes may grow to be very long, reaching 165 cm total length (Stebbins 2003).

The giant garter snake is highly aquatic, frequenting slow-moving waterways, such as sloughs and other mud-bottomed wetlands (Stebbins 2003). Giant garter snakes prefer wetland habitat where there is screening vegetation in and adjacent to the water. Researchers in the Sacramento Valley found telemetered giant garter snakes associated with vegetative cover in 94% of observations (Wylie et al.[3] 2002). Screening vegetation, such as shrubby willows, Salix sp., is thought to provide protection from predators, while still allowing the snake to thermoregulate (Hansen[4] 1988). Giant garter snakes pursue prey underwater (Hansen[4] 1988). Their historic prey included Sacramento

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[2] Hansen, G. E. and J. M. Brode. 1980. Status of the giant garter snake *Thamnophis couchi gigas* (Fitch). California Department of Fish and Game Inland Fisheries Endangered Species Program, Special Publication Report No. 80-5, unpublished. Sacramento, CA.

[3] Wylie, G. D., M.L. Casazza and N.M. Carpenter 2002. Monitoring giant garter snakes at Colusa National Wildlife Refuge: 2001 progress report. US Geological Survey, Western Ecological Research Center, Dixon Field Station, Dixon, CA.

[4] Hansen, G. E. 1988. Review of the status of the giant garter snake (*Thamnophis couchi gigas*) and its supporting habitat during 1986-1987. Final unpublished report to the California Department of Fish and Game, Standard Agreement No. C-2060.

blackfish, *OrthodoN microlepidotus*, thick-tailed chub, *Gila crassicauda*, and red-legged frogs, *Rana aurora draytonii*, none of which are currently available to giant garter snakes. They now take introduced carp, *Cyprinus carpio*, mosquitofish, *Gambusia affinis*, and bullfrogs, *Rana catesbiana* (Rossman et al. 1996).

Agricultural development has impacted giant garter snake populations through habitat destruction and through pesticide and herbicide runoff and drift. Irrigation has increased levels of selenium in some Merced County waterways (Moore et al.[5] 1990) and may impact snake populations. It is interesting to note though, that giant garter snake populations have declined on protected lands such as the Volta and Mendota wildlife areas that have neither received selenium rich agricultural drain water, nor experienced conversion of habitat to agricultural land. More research is needed to understand giant garter snake decline in these areas.

Other threats to giant garter snake populations include urbanization and introduced predators. The Central Valley is rapidly becoming an urbanized environment. For example, the city of Los Banos, located in Merced County, has experienced a 38.7% increase in population between 1990 and 2000 (U.S. Census Bureau, www.census.gov). This city lies between the northern and southern divisions of the Grassland Ecological Area (GEA) and its growth could have direct and indirect impacts on giant garter snake populations.

Introduced predators may reduce the quality of remaining habitat in the San Joaquin Valley. Bullfrogs and introduced predatory fish may prey heavily upon giant garter snake neonates (Carpenter et al. 2002). In addition to becoming prey to introduced species, giant garters snakes may be killed while attempting to ingest introduced bullheads, *Ictalurus* sp., whose sharp spines can become lodged in a snake's throat and prevent ingestion or regurgitation thus killing the snake (G. Wylie, U.S. Geological Survey, personal communication). Both predation by introduced predators and mortality due to ingestion of introduced bullheads have been documented in the Sacramento Valley where giant garter snakes appear to be more abundant than in the San Joaquin Valley. While introduced species undoubtedly play some role in giant garter snake ecology, more research is needed to ascertain the nature of these impacts. It is possible that the seasonal reduction of available habitat in summer forces aquatic introduced species and giant garter snakes into a greater number of interactions as San Joaquin Valley wetlands and canals are drawn down for water saving measures or for maintenance purposes.

Based on estimates of habitat loss throughout its range, California Department of Fish and Game (DFG) listed the giant garter snake as Rare in 1971. Surveys conducted in the mid – 1970's suggested the range of the giant garter snake in the San Joaquin Valley was reduced from its historic boundaries, but populations still existed in the central and northern parts of the valley (Hansen and Brode[2] 1980). Follow up surveys in 1986 and 1987 failed to find any giant garter snakes in the San Joaquin Valley, although

[5] Moore, S., J. Winckel, S. Detwiler, S. Klasing, and P. Gaul. 1990. Fish and wildlife resources and agricultural drainage in the San Joaquin Valley: volume one, section 1. San Joaquin Valley Drainage Program Report, Library Reference #: 6117. Sacramento, CA

time spent at sites in the San Joaquin Valley was described as "limited" by the researchers (Hansen[5] 1988). When the California Endangered Species Act was passed in 1984, the giant garter snake was designated Threatened (California Fish and Game Code §2050-2116) due primarily to habitat loss throughout its range (California Department of Fish and Game[6] 2000). The giant garter snake was also listed as Threatened under the Federal Endangered Species Act in 1993 (US Fish and Wildlife Service 1993).

In 1998, US Geological Survey Biological Resources Division (USGS) researchers headed a cooperative effort to survey sites in the San Joaquin Valley for giant garter snakes. Through this partnership between the USGS, DFG, U.S. Fish and Wildlife Service, and Grassland Water District (GWD) giant garter snakes were documented on the Volta Wildlife Area, but not on the Mendota Wildlife Area (Table 1). Beginning in 1999, DFG conducted giant garter snake surveys in the San Joaquin Valley, working collaboratively with GWD to gain access to privately owned lands. The goal of DFG's 2001 trapping effort was to document giant garter snake populations in the southern section of the GEA and on the Mendota Wildlife Area, two places where they were known to occur historically.

Table 1. Trap sites, trap-days, and trapping effort per giant garter snake in northern San Joaquin Valley giant garter snake surveys, 1998 – 2001

	1998 (28,238 total trap days)		
Trap site[a]	Trap-days	# GGS[b] captured	Trap-days/ GGS captured
Bennet Ditch	1764	0	NA
Canal 1	1581	1	1581
LBWA Fields 37and 27	1598	0	NA
LBWA, Mud Slough Ditch 7/9	1581	0	NA
Mud Slough Site 4	1564	0	NA
Mud Slough Site 5	1746	0	NA
MWA, Ditch 5 3/54	1615	0	NA
MWA, Field 17/18	1513	0	NA
MWA, Hamburger Ditch	1800	0	NA
MWA, Tin Can Slough	2879	0	NA
North GEA	3813	7	545
Salt Slough WA	1547	0	NA
San Joaquin NWR, Riley Slough	1190	0	NA
San Luis NWR, C-Canal	1600	0	NA
Santa Fe Canal	1547	0	NA
VWA Site 3	900	3	300

[6]California Department of Fish and Game. 2000. The status of rare, threatened, and endangered animals and plants of California – Annual report for 2000. Habitat Conservation Planning Branch, California Department of Fish and Game, Sacramento.

(Table 1 continued)

1999 (19,780 total trap days)

Trap site	Trap-days	# GGS captured	Trap-days/ GGS captured
LBWA, Fields 36 & 39	1530	0	NA
North GEA	8250	6	1375
VWA Site 1	7875	5	1575
VWA Site 3	2125	3	708

2000 (27,875 total trap days)

Trap site	Trap-days	# GGS captured	Trap-days/ GGS captured
LBWA, Field 42	5250	0	NA
Mud Slough Site 2	13875	8	1734
Mud Slough Site 3	4500	0	NA
VWA Site 1	4250	0	NA

2001 (56,689 total trap days)

Trap site	Trap-days	# GGS captured	Trap-days/ GGS captured
Canal 1	4074	1	4074
Mud Slough Site 1	16267	0	NA
MWA Site 1	11906	18	661
MWA Site 2	6400	0	NA
MWA Site 3 and Alkali Sink ER	4172	0	NA
MWA, Pump 4	4470	0	NA
MWA, Tin Can Slough	4000	0	NA
VWA Site 1	3400	0	NA
VWA Site 2	2000	0	NA

[a] Precise locations are available from DFG's California Natural Diversity Database.
[b] Giant garter snake (GGS).

STUDY AREA

We had four study areas in Merced and Fresno counties; northern GEA (two sites), southern GEA (four sites), Mendota Wildlife Area (six sites) and Alkali Sink Ecological Reserve (one site). At approximately 64,752 ha, the GEA of western Merced County, contains the largest contiguous block of wetlands remaining in the Central Valley (Fredrickson and Laubhan[7] 1995). In the northern GEA (Fig. 1), we surveyed a 3-km long

[7] Fredrickson, L. H. and M. K. Laubhan 1995. Land use impacts and habitat preservation in the grasslands of western Merced County, California. Unpublished report to Grassland Water District.

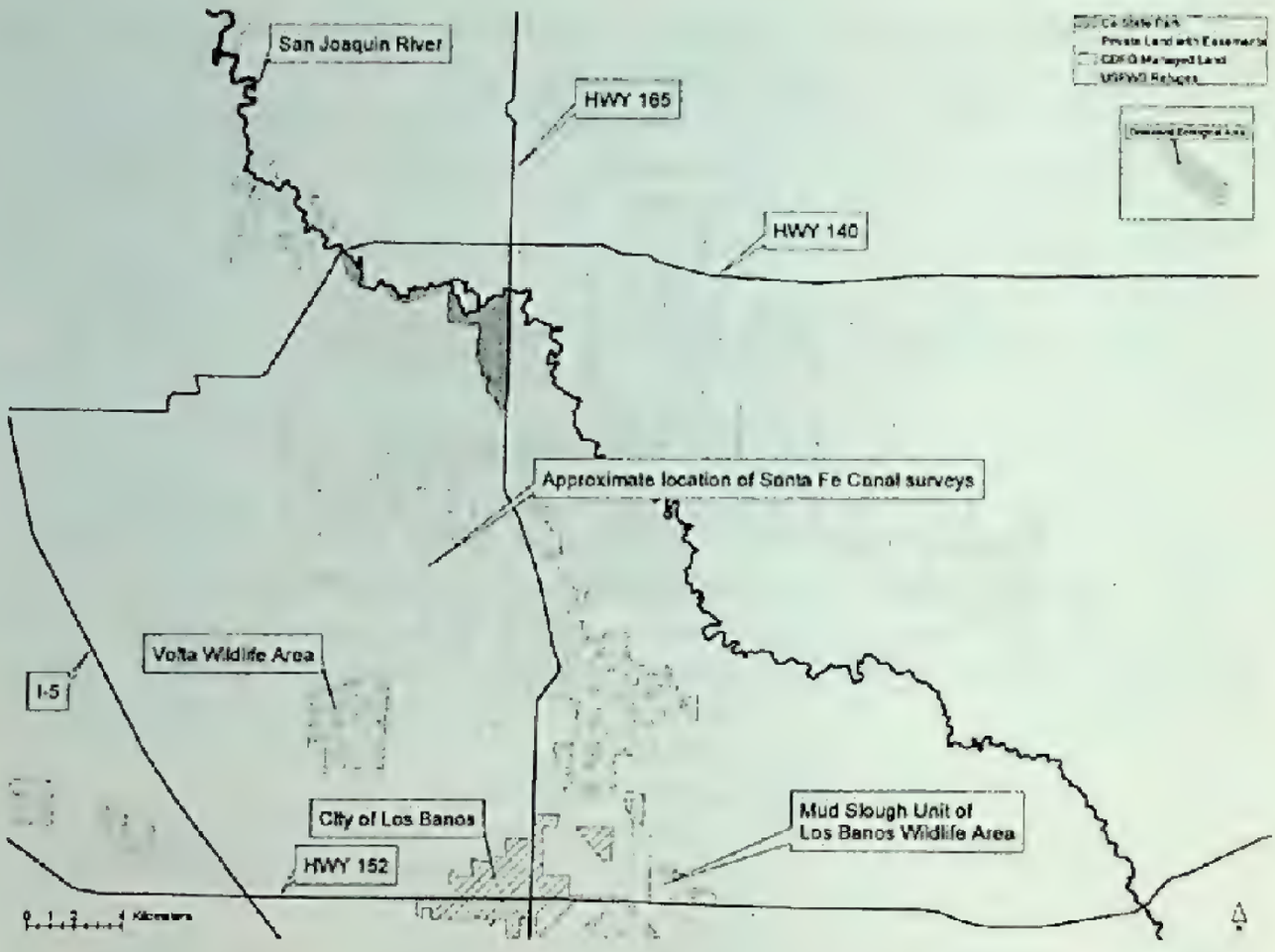

Figure 1. The northern portion of the Grassland Ecological Area in western Merced County, California.

section of the Santa Fe Canal that runs through privately owned lands. The canal is surrounded by private duck clubs and agricultural lands, which produce cotton and alfalfa. The dominant vegetation along the canal was tule, *Scirpus acutus*, and cattail, *Typha* sp., although yellow star-thistle, *Centaurea solstitialis*, and pepperweed, *Lepidium latifolium*, occurred in patches.

The Volta Wildlife Area is owned by the Bureau of Reclamation and managed by DFG. It is located near the hamlet of Volta, Merced County, approximately 11 km northwest of the city of Los Banos (Fig. 1). Volta survey areas held water throughout the year and were dominated by tule, but had pepperweed in some areas. In 1998 and 1999 we captured and PIT (passive integrated transponder) tagged giant garter snakes at the Volta Wildlife Area (Table 1). In 1999 we did not capture any snakes that had been captured and PIT tagged in 1998. No giant garter snakes were captured at Volta in 2000. We surveyed the Volta Wildlife Area in 2001 in an attempt to recapture snakes from previous years' surveys as well as capture and mark new snakes.

Survey sites in the southern GEA (Fig. 2) included Canal 1, Mud Slough, Britto Ditch, and Double D Ditch. Canal 1, Britto Ditch, Double D Ditch and part of Mud Slough run through privately owned land managed as duck clubs. The remainder of Mud Slough runs through the Gadwall Unit, North Grasslands Wildlife Area. Giant garter

snakes were captured in a stretch of Mud Slough in 2000 (Table 1). We selected a section of Mud Slough downstream of this site with a different vegetation community for our surveys in 2001. Mud Slough, as well as Canal 1, Britto Ditch, and Double D Ditch supported typical marsh vegetation including juncus, *Juncus* sp., and tule, as well as invasive weeds such as yellow star thistle and pepperweed on their banks. The water depth in these waterways was variable, ranging from about 0.3 – 1.5 m, depending on specific location and amount of water moving through them.

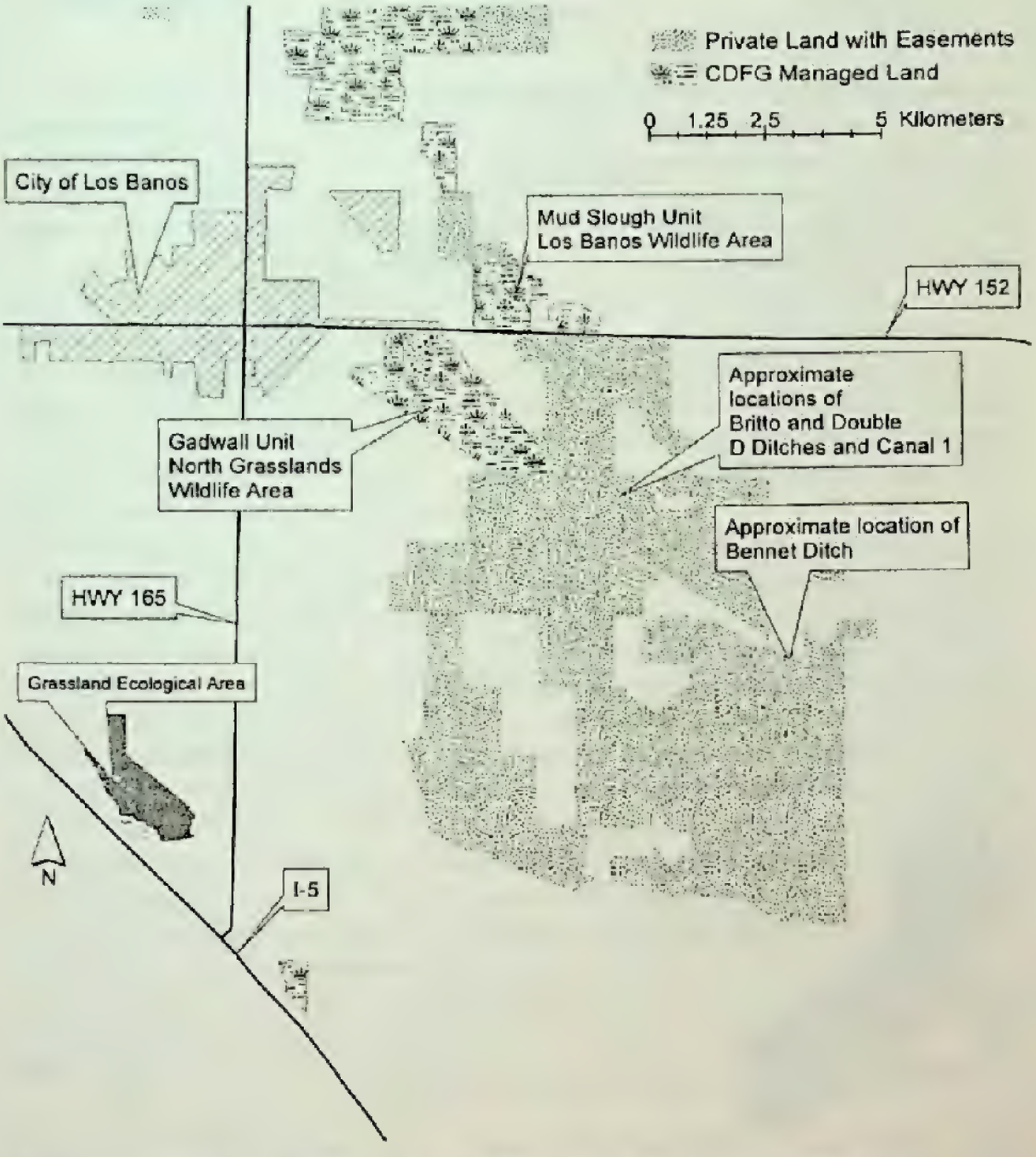

Figure 2. The southern portion of the Grassland Ecological Area in western Merced County, California.

The Mendota Wildlife Area and Alkali Sink Ecological Reserve are adjacent to one another in Fresno County (Fig. 3). DFG manages the Mendota Wildlife Area primarily for wintering waterfowl. It is located approximately 5 km southeast of the city of Mendota in Fresno County (Fig. 3). We focused on areas where biologists found snakes when they were more common in that vicinity (Hansen and Brode, unpublished

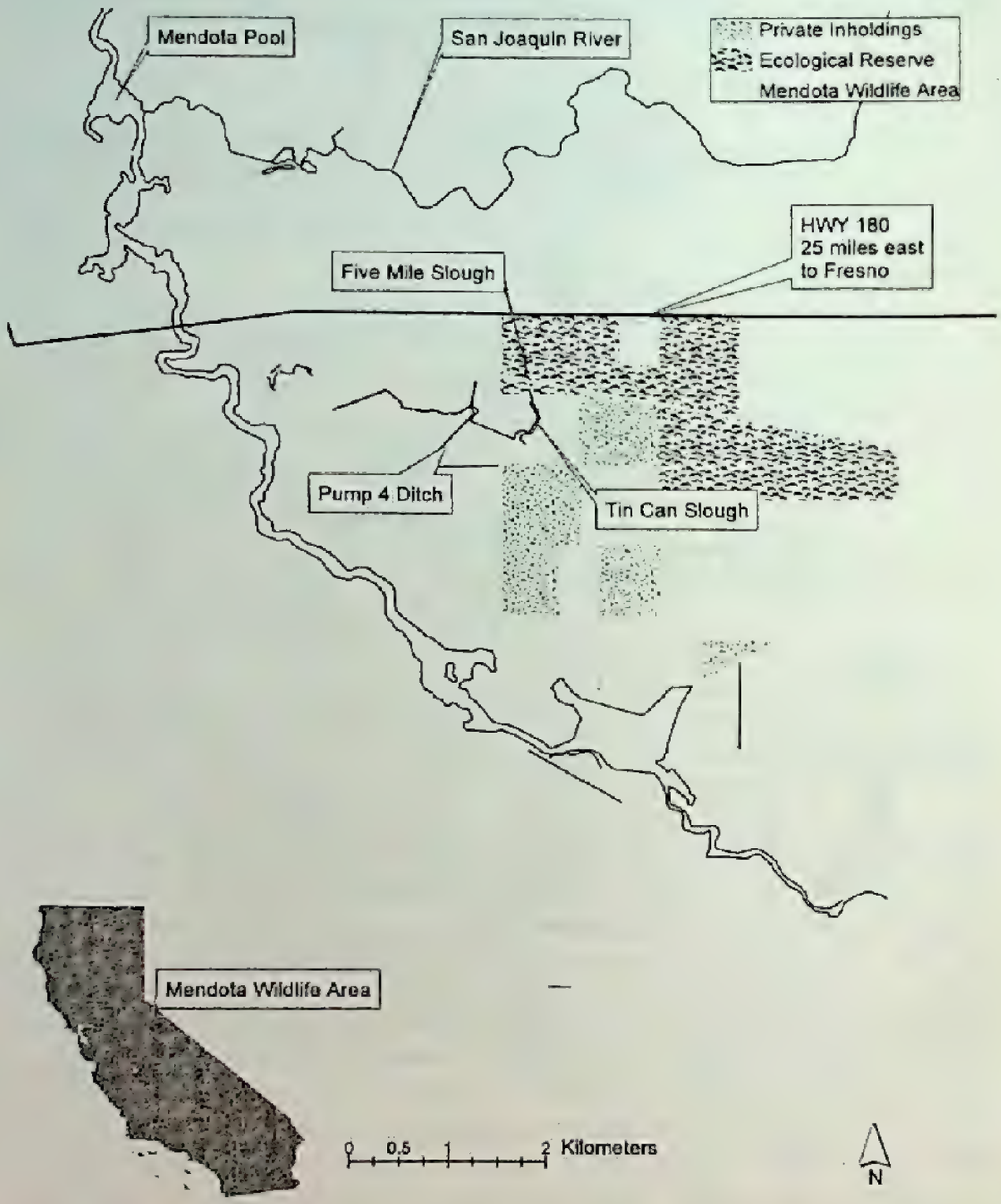

Figure 3. The Mendota Wildlife Area and Alkali Sink Ecological Reserve located in Fresno County, California.

data, S. Brueggemann, California Department of Fish and Game, personal communication). The banks of surveyed waterways at the Mendota Wildlife Area had primarily tule and cattail edges, although at some trap sites juncus, iodine bush, *Allenrolfea occidentalis*, and saltgrass, *Distichlis spicata*, were common.

Finally, we surveyed Five Mile Slough at the Alkali Sink Ecological Reserve. This ecological reserve is located in Fresno County, adjacent to the Mendota Wildlife Area (Fig. 3). It is managed by DFG primarily for threatened and endangered species protection. Juncus was the dominant vegetation along Five Mile Slough.

METHODS

We visually searched for giant garter snakes by walking areas that were slated for habitat maintenance, habitat where snakes had been found historically, and in wetlands where traps were set. We performed visual surveys at all trap sites, as well as at the Santa Fe Canal, Britto Ditch, and Double D Ditch. We conducted visual giant garter snake surveys in accordance with U.S. Fish and Wildlife Service protocols for avoidance of take of giant garter snakes during construction activity (U.S. Fish and Wildlife Service[8] 2000). This survey protocol was developed in order to prevent incidental take of giant garter snakes during construction activities in snake habitat. The visual surveys were not developed to determine presence or absence of giant garter snakes at specific sites. Failure to find giant garter snakes using visual surveys does not indicate the species' absence at that location, especially at San Joaquin Valley sites with low population density. Visual surveys took place in early morning when snakes were likely to be basking and most visible.

We set traps for giant garter snakes at Canal 1, Mud Slough, Alkali Sink Ecological Reserve, and the Volta and Mendota wildlife areas. We trapped giant garter snakes in modified eel pot traps placed approximately 10 m apart along banks or attached to emergent vegetation of study sites, although bank conditions often caused this spacing to vary. Total number of traps per site varied according to site conditions. Modifications to traps included widening openings to allow snakes to enter and attachment of Styrofoam floats that kept part of the trap above water level (Casazza et al. 2000). Traps remained at each site for at least 14 days before being relocated. We checked traps daily either by boating or walking the trap line. At each trap, we recorded the vegetation directly next to it. We recorded the air temperature at the beginning and end of each trap line each day. We recorded all potential prey that we captured in traps.

We recorded morphological measurements to positively identify captured snakes to species. These measurements included counts of supralabials, infralabials, preoculars, postoculars, and dorsal scale rows at mid-body. We also measured physical characteristics such as snout to vent length (SVL) and mass, and we implanted PIT tags. Finally, we sketched each snake and indicated the location of any cysts or lumps we

[8] US Fish and Wildlife Service 2000. Biological opinion for the Central Valley Project Improvement Act's programmatic environmental impact statement report. Unpublished report by the US Fish and Wildlife Service.

noticed on the snakes' bodies. We used global positioning system (GPS) to digitally record capture locations and incorporated all 2001 giant garter snake capture locations into a geographic information system (GIS) that includes capture locations for trap years 1998 through 2001. All giant garter snake capture locations were made available for inclusion in the California Natural Diversity Database. We released captured giant garter snakes at the capture site, usually on the day following their capture.

I used NCSS 2000 software (Hintz[9] 2001) for statistical analysis. I compared means using two-sample t-tests. For comparison of mean air temperature on days when snakes were captured to days when no snakes were captured I used the Wilcoxon Rank-Sum test due to lack of normal distribution of these data. I used the Aspin-Welch t-test for all other tests due to unequal variance of samples.

RESULTS

DFG personnel used the same trap design and trapping protocol while conducting surveys in the San Joaquin Valley from 1998-2001. Trap effort has varied from year to year (Table 1). I have presented the results from surveys DFG conducted from 1998 through 2000 for comparison to the results of surveys we conducted in 2001.

We captured 15 giant garter snakes in 2001. Four of these snakes were recaptured that season, for a total of 19 captures. The average mass of these snakes was 170.3 g (S. E. = 22.4) and the average snout to vent length (SVL) was 652.3 mm (S. E. = 24.8) (Fig. 4). Male and female giant garter snake mass and SVL did not differ significantly ($t = 0.21$, $df = 1$, $P \approx 0.833$ and $t = 0.97$, $df = 1$, $P \approx 0.348$ respectively), although there was greater variation in mass and SVL within females than within males. One giant garter snake female, captured at the Mendota Wildlife Area accounted for much of that variation. Her mass was 410 g and SVL was 850 mm. Average mass for all females captured in 2001 was 165 g (S. E. = 42.7). Average SVL for all females was 626.4 mm (S. E. = 46.1). Male mass averaged 175 g (S. E. = 22.5) and SVL averaged 675 mm (S. E. = 23.8). We captured 8 males and 7 females in total.

We captured only one giant garter snake in the southern GEA, at Canal 1. This was a 125 g male, which was afflicted with several unidentified cyst-like lumps. In Canal 1, the dominant vegetation next to our traps was the invasive aquatic weed, parrot's feather (*Myriophyllum aquaticum*). There were areas that supported juncus and tule as well.

We captured 14 giant garter snakes in one waterway on the Mendota Wildlife Area where most traps were attached to tule and cattail. We caught 7 males ranging in size from 500-772 mm SVL (95-295 g) and 7 females ranging from 500-850 mm SVL (75-410 g). Five of the 14 snakes had cyst-like lumps on their bodies, similar to those seen on the snake captured in Canal 1. We did not capture giant garter snakes at any other sites at Mendota, although valley garter snakes, *Thamnophis sirtalis fitchi*, were abundant in several of these waterways.

[9]Hintze, J. 2001. NCSS and PASS. Number Cruncher Statistical Systems. Kaysville, Utah.

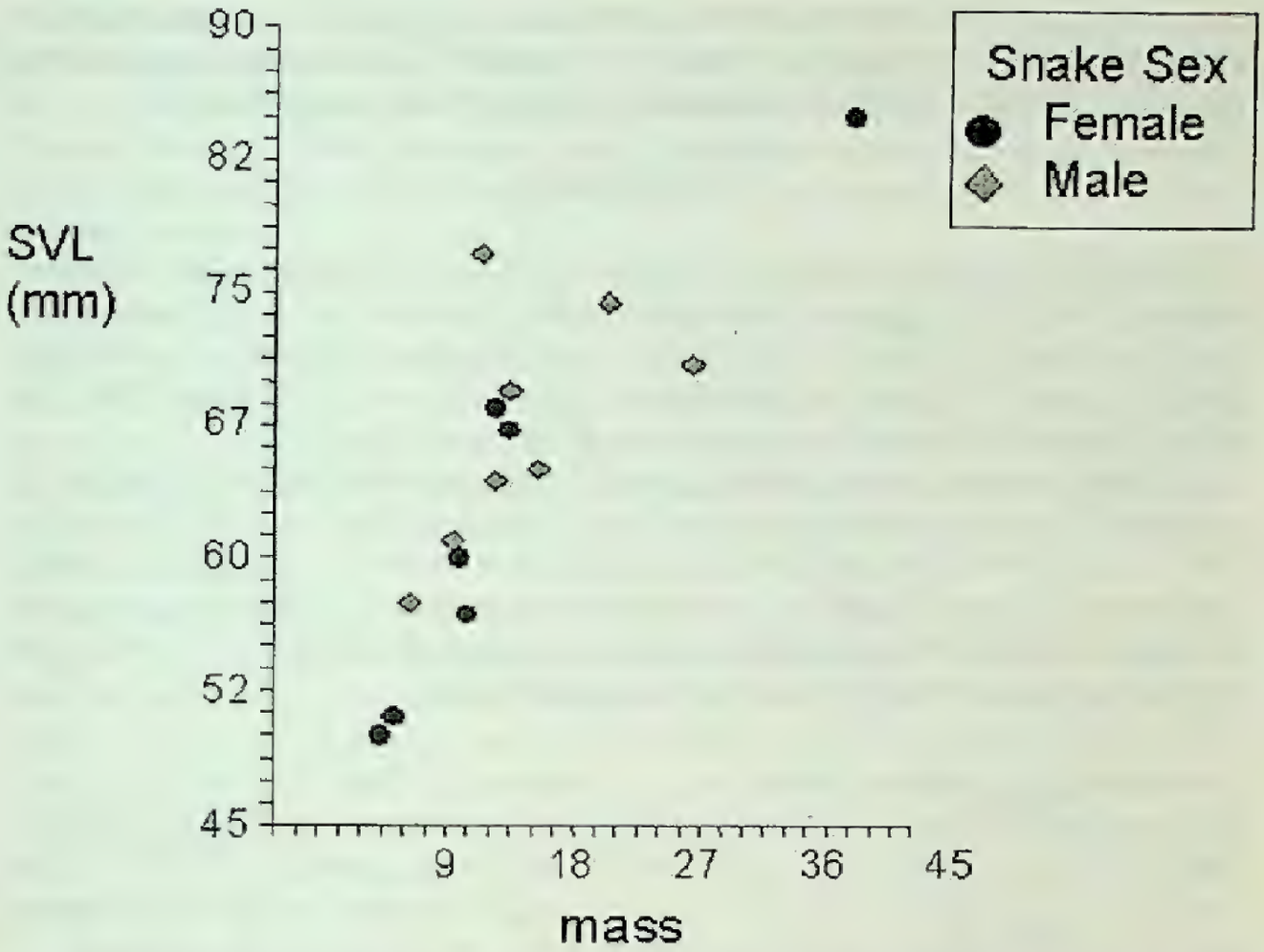

Figure 4. Mass and SVL of giant garter snakes captured in northern San Joaquin Valley surveys in 2001.

No giant garter snakes were captured in Mud Slough. The traps here were surrounded by invasive pepperweed. Exotic poison hemlock, *Conium maculatum*, was also present.

We did not capture any giant garter snakes at the Volta Wildlife Area. Tule and cattail were the dominant vegetation at trap sites, although there was pepperweed mixed in with these plants in some areas. Valley garter snakes were commonly captured in traps set for giant garter snakes at Volta Wildlife Area sites.

No giant garter snakes were seen or captured in visual surveys conducted at any location. This includes visual surveys performed at sites where snakes were captured in traps in 2001.

The average air temperature on days when giant garter snakes were captured (29.0 °C) was slightly higher than the average air temperature on non-capture days (27.0 °C) though not significantly so.

I calculated the average percentage of traps at each site that captured potential prey items. At trap sites where giant garter snakes were captured, the percentage of traps that also contained potential prey items was not among the highest or lowest when all trap sites were considered. From 18%-25% of the traps set in sites where giant garter

snakes were captured contained potential prey, while 7.3% - 60.9% contained potential prey items where no giant garter snakes were captured. The most common potential prey items included fish such as mosquito fish, cyprinids, and centrarchids.

DISCUSSION

Our trapping efforts resulted in capture of 15 giant garter snakes from two populations in 2001. Since surveys began in 1998, five populations have been located in the northern San Joaquin Valley (Table 1). The population located on the Mendota Wildlife Area in 2001 was the first in Fresno County since surveys began in 1998. The remaining populations are located in western Merced County.

Although there were no significant differences between males and females in average SVL or mass for snakes captured in 2001, when all data collected between 1998 and 2001 are pooled, females have significantly greater mass ($t = 3.6$, $df = 1$, $P \approx 0.001$) and longer SVL ($t = 2.83$, $df = 1$, $P \approx 0.005$) than males (Fig. 5). The small sample size collected in 2001 is the most likely cause for the lack of significance in difference between males and females in terms of mass and length.

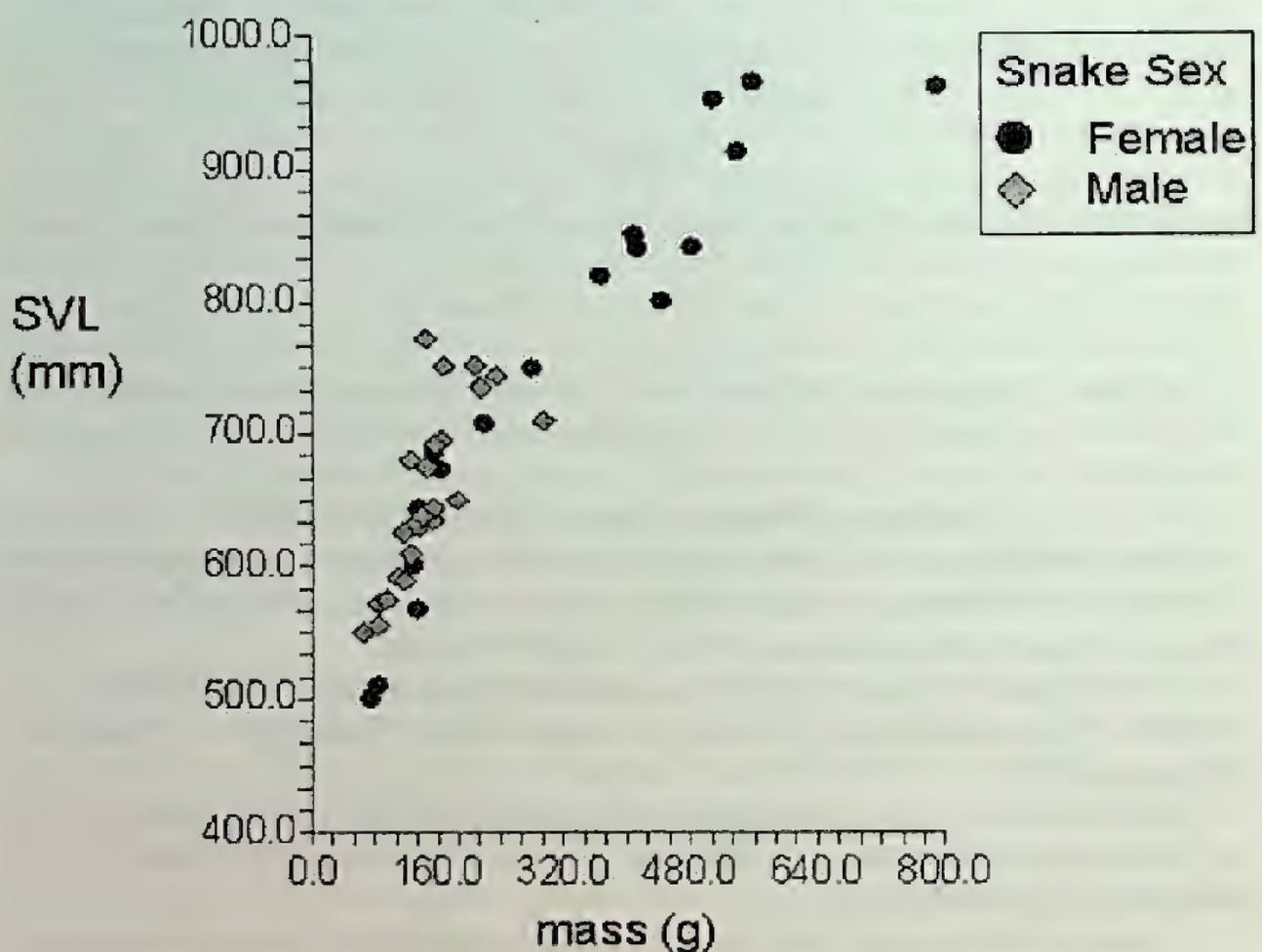

Figure 5. Giant garter snake mass and SVL for all snakes captured in northern San Joaquin Valley surveys from 1998 through 2001.

The smallest snake captured in 2001 was 500 mm in length, well above the mean neonatal length of 206.4 mm (Rossman et al. 1996). This could reflect a true scarcity of neonates in San Joaquin Valley populations or it could be reflective of trap design bias. Young snakes may be able to escape from the modified funnel traps more easily than adults. An investigation into alternative trap designs might lead to discovery of a more efficient trap design.

Knowledge of temperature and seasonal effects on our ability to catch snakes could improve our capture rates for giant garter snakes. While average air temperatures were slightly warmer on days that giant garter snakes were captured than on non-capture days, there were essentially only two capture sites, Canal 1 and Mendota Wildlife Area, and only one snake was captured in Canal 1. Since most snakes were captured in just one location, over a short time period, this result probably indicates the site conditions at Mendota Wildlife Area in June and may have little applicability to giant garter snake habitat in general.

Because we had only two capture locations, we cannot generalize about which vegetation communities are preferred giant garter snake habitat. The Mendota Wildlife Area site was bordered by tule and cattail, but at Canal 1 parrot's feather was a major component of the wetland edge plant community. We also trapped sites on the Mendota Wildlife Area that supported atriplex, *Atriplex* sp., and saltgrass communities, but did not capture giant garter snakes at these sites. Conversely, there were survey sites at both the Mendota and Volta Wildlife Areas that supported tule and cattail vegetation where no snakes were found.

Some sites that we trapped in 2001 supported populations of valley garter snakes, but no giant garter snakes were captured. Valley garter snakes were seen in and around waterways and were also captured in floating funnel traps set for giant garter snakes. Sites at the Volta and Mendota wildlife areas supported what appeared to be large numbers of valley garter snakes in some wetlands. Valley garter snake densities could not be determined since these snakes were not marked prior to release. Understanding niche use and life history differences between valley and giant garter snakes may help determine why no giant garter snakes were found in waterways where valley garter snakes appeared to be successful.

The most important outcome of this survey was the location of a population of giant garter snakes at the Mendota Wildlife Area. This area was surveyed in the late 1970's (Hansen and Brode[2] 1980), mid 1980's (Hansen[4] 1988) and in 1995 (Hansen[10]). These surveys relied primarily on visual observation of giant garter snakes instead of trapping. Giant garter snakes were found on the Mendota Wildlife Area in the late 1970's, but were not seen in the later surveys. Visual observation may be a less reliable method of detecting giant garter snake presence than trapping. For example, in this study a giant garter snake was trapped at Canal 1 where visual surveys conducted prior to and after the capture date failed to find any giant garter snakes. In 2001, we focused

[10] Hansen, G. E. 1995. Status of the giant garter snake (*Thamnophis gigas*) in the San Joaquin Valley – 1995. Final unpublished report to the California Department of Fish and Game, Standard Agreement No. FG4052IF.

our trapping efforts on Mendota Wildlife Area waterways where giant garter snakes had been encountered previous to 1980, but found snakes at only one of these locations. This population is now the southern-most recently documented population of this species that once ranged into Kern County. While most of the giant garter snake habitat in the Tulare Lake Basin, including Tulare and Buena Vista lakes, no longer exists, there is a small possibility that giant garter snakes are extant in remnant habitats. Formal surveys for giant garter snakes in remaining suitable habitat fragments could determine their status there.

Another interesting outcome of this work is our failure to capture giant garter snakes from the Volta Wildlife Area population. Three giant garter snakes were captured in mid-August at the Volta Wildlife Area in 1998 (Table 1). Eleven snakes were captured and marked at Volta from the end of March through the end of June in 1999 (Table 1). Trapping took place in September of 2000 at Volta Wildlife Area and August 2001, but no giant garter snakes were captured there either year. It is unclear whether we have simply failed to locate this population of giant garter snakes or if it has been extirpated. Trapping in both 2000 and 2001 occurred late in the trapping season and the timing of trapping could explain the failure to capture snakes these years. An expanded trapping effort over a longer time frame may enable us to locate this population.

Several giant garter snakes that we found had unidentified lumps on their bodies. Five of the 14 snakes captured at Mendota Wildlife Area, and the snake captured in Canal 1 had these abnormalities. The cause of these lumps should be identified in the near future in order to determine if a parasite or other disease is attacking giant garter snakes. Giant garter snakes have experienced declines in areas of the San Joaquin Valley such as state-managed wildlife areas and other protected areas. Factors such as disease could be in part responsible for giant garter snake decline in areas where obvious factors such as habitat destruction and contaminated water can be ruled out.

In order to best manage areas for giant garter snake conservation, it is necessary to understand the habitat requirements of giant garter snakes in the San Joaquin Valley, how habitat requirements might differ from general habitat requirements documented in the Sacramento Valley, and the factors that are limiting giant garter snake recovery in the San Joaquin Valley. Successful restoration and repatriation efforts on state and federally managed lands will depend on accurate habitat characterization, determination and removal of threats to species recovery, and understanding of the current status and distribution of this species. This information is also essential for understanding the management impacts on giant garter snake populations. Private land owners also benefit from this knowledge since it allows them to manage their duck clubs while minimizing impact to giant garter snakes. Implantation of radio-transmitters in giant garter snakes would be an excellent method to discover many details of giant garter snake habitat requirements. Studies of giant garter snake habitat use in the San Joaquin Valley would complement those currently being conducted by the USGS in the Sacramento Valley. Differences in habitat use by snakes in the two valleys are possible because of differences in soil type and vegetation composition between these two bioregions. Climate and water availability differ between these two areas and may influence giant garter snake habitat use. For example, not only does less rain fall in the

San Joaquin Valley annually (Western Regional Climate Center http://www.wrcc.sage.dri.edu/narratives/CALIFORNIA.htm), but its warmer climate promotes rapid moist soil plant growth in spring allowing wetland managers to draw wetlands down 2–4 weeks earlier in the San Joaquin Valley (Reid 1995). Interaction of these factors may affect giant garter snake habitat use and survival. Unfortunately, due to the low numbers of giant garter snakes present in northern San Joaquin Valley populations, and mortality associated with radio implantation, U.S. Fish and Wildlife Service could not permit this action (K. Hornaday, U.S. Fish and Wildlife Service, personal communication 2001). Another obstacle to use of this method is that most of the snakes we captured in the 2001 trapping season were too small to have radio-transmitters surgically implanted (G. Wylie, U.S. Geological Survey, personal communication). Research into new trap design, intended to capture larger snakes, or use of a less invasive methodology for transmitter deployment, may make radio tracking of giant garter snakes feasible in the San Joaquin Valley.

Information gleaned from trapping surveys is valuable however for learning general habitat characteristics and giant garter snake population locations. This knowledge of giant garter snake distribution and habitat requirements could lessen impact to snakes and habitat during maintenance of water delivery systems and aid land managers in balancing the goals for waterfowl management with giant garter snake conservation.

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PINTAIL DISTRIBUTION AND SELECTION OF MARSH TYPES AT MENDOTA WILDLIFE AREA DURING FALL AND WINTER

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To help guide management of Mendota Wildlife Area (MWA), we determined distribution patterns and use relative to availability (i.e., selection) of lake vs. shallow marsh, and shallow marsh by dominant understory vegetation and percentage of emergent cover during September through March, 1991-94 for 145 female northern pintails, *Anas acuta*. Pintails were radio tagged during August - early October at MWA (n = 116), other San Joaquin Valley areas (n = 27), or Suisun Marsh (n = 2). Before duck hunting season (i.e., Prehunt), pintail distribution at MWA generally tracked marsh flooding although distribution was more concentrated during the day than night. During duck hunting season (i.e., Hunt), pintails that had not left MWA sought sanctuary on units closed to shooting and at night dispersed throughout the area; most returned to sanctuary units on both shoot (Wednesdays and weekends) and nonshoot days. Pintails present during Posthunt (i.e., after Hunt ended) dispersed throughout MWA. Pintails avoided the central lake in favor of the more shallow marsh units throughout MWA. Among the marsh units, pintails selected open and avoided heavily vegetated units at night. Open marsh units were also selected during the day during Posthunt and, except in 1993, during Prehunt. However, closed or hemi marshes were selected during day during Hunt. Marshes where swamp timothy, *Heleochloa schoenoides*, was the dominant or prominent understory plant were always selected and received more use by pintails than any other marsh type. Watergrass, *Echinochloa crusgalli*, marsh was avoided during the day but, along with timothy marsh, selected at night most years. Selection of marsh where alkali bulrush, *Scirpus paludosus*, or other non-timothy or non-watergrass plants were primary understory plants ranked in the middle during the day but were avoided at night. Our finding that foraging pintails selected swamp timothy is consistent with food habits and habitat use reported elsewhere, but the

greater use of watergrass marsh at MWA than in the Grassland Ecological Area indicates regional differences in management or pintail ecology. Exodus of pintails coinciding with start of Hunt indicates that some aspect of the sanctuary or other habitats were lacking at MWA, and will need to be improved to maintain pintail use all winter.

INTRODUCTION

The Mendota Wildlife Area (MWA) wetland complex in California's San Joaquin Valley lies between important waterfowl wintering habitats in the vicinity of Kern National Wildlife Refuge (NWR), 100 km to the southeast, and the Grassland Ecological Area, 50 km to the northwest (Fig. 1). The MWA supports large concentrations of northern pintails, *Anas acuta*, and other waterfowl while providing recreation to thousands of hunters, fishermen, wildlife watchers, and others pursuing an outdoor experience. Surrounded by crop fields that are mostly plowed after harvest and left dry, waterfowl wintering at MWA rely almost entirely upon wetland resources within the MWA. Thus, the need to provide preferred habitats and intensively manage those habitats for maximum productivity is especially crucial. To accomplish their mandate of providing for the needs of wintering waterfowl, managers require information on how important waterfowl species such as northern pintails use the area and select among the variety of marsh types that are available at MWA.

Although pintail distribution, habitat use, and selection have been reported for other San Joaquin Valley areas (Fleskes et al. 2002a, 2003, 2004), the dynamics of pintail distribution at MWA and use and selection from among the mix of marsh types available there have not been studied. MWA is comprised of numerous marsh units of known vegetation composition and flooding regime, all well within the maximum daily flight range of pintails (43 km, Fleskes 1999) roosting in the central sanctuary or elsewhere on the area, and is surrounded by dry agricultural lands. Thus, MWA provides an excellent setting to test habitat use relative to availability (i.e., selection) by pintails.

Roosting and foraging are primary activities of pintails wintering in California (Miller 1985). Pintails feed extensively at night during all seasons, with most roosting occurring during the day. However, time spent roosting during day is reduced due to extensive day feeding before duck hunting season (i.e., Prehunt) to replenish fat reserves depleted by breeding and fall migration and after hunting season (i.e., Posthunt) to prepare for spring migration and nesting (Euliss[1] 1984, Miller 1985, 1986). Thus, habitat use at night throughout the September - March wintering period mainly reflects foraging site selection, daytime use during hunting season (i.e., Hunt) mainly reflects loafing site selection, and daytime use before and after hunting season reflects both foraging and loafing site selection.

To provide information for wetland habitat managers, we studied use of MWA by

[1]Euliss, N. H., Jr. 1984. The feeding ecology of pintail and green-winged teal wintering on Kern National Wildlife Refuge. Thesis, Humboldt State University, Arcata, California, USA.

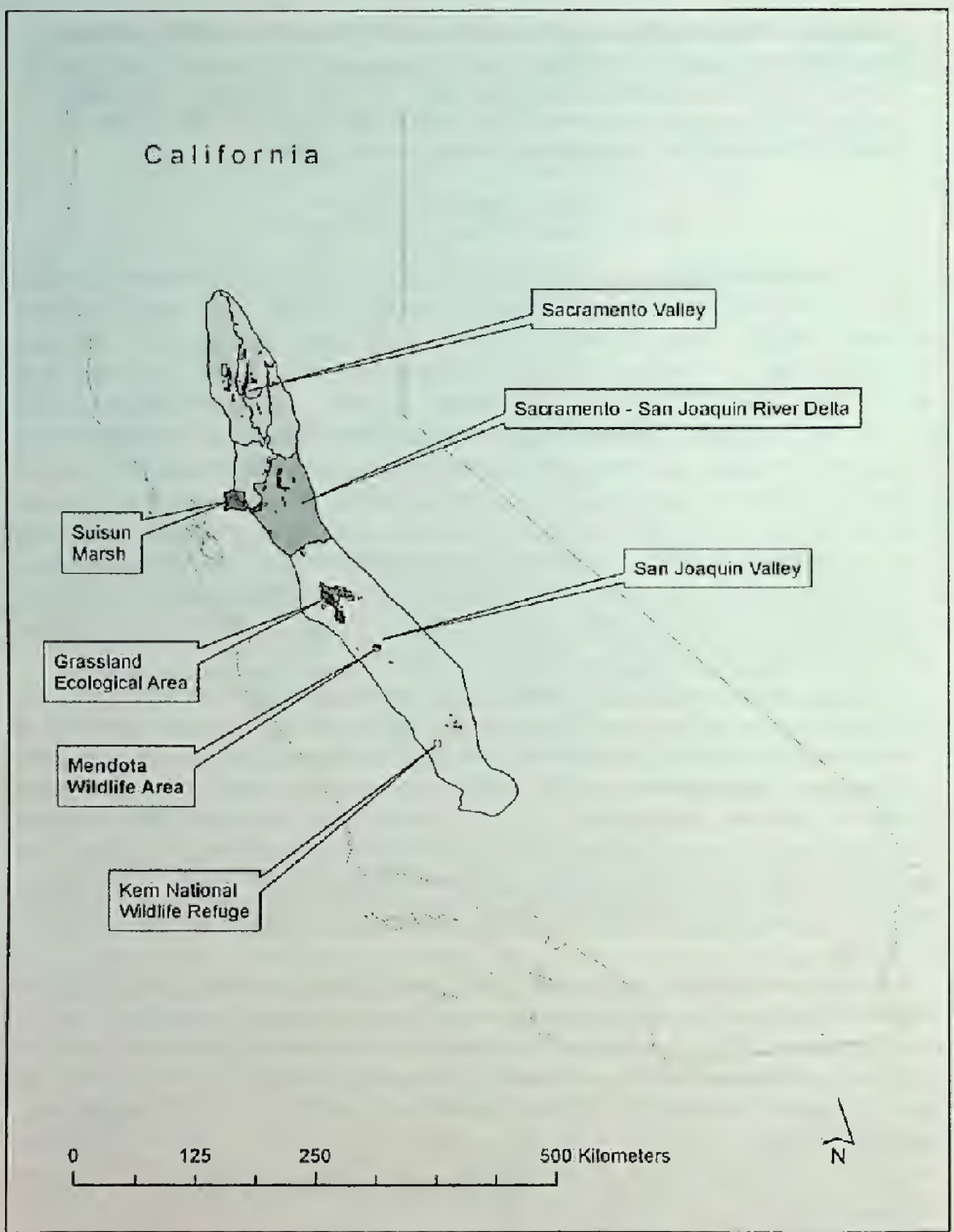

Figure 1. The Mendota Wildlife Area (MWA) in the San Joaquin Valley of California's Central Valley. Habitat use and selection by female northern pintails, *Anas acuta*, in the MWA were studied during September - March, 1991-94 for 145 pintails that were radio tagged in the MWA, Grassland Ecological Area (50 km northwest of the MWA), the Tulare Basin near Kern National Wildlife Refuge (100 km southeast of the MWA), or the Suisun Marsh (230 km northwest of the MWA).

female northern pintails, during September through March, 1991-94. We studied only females because they are especially important to population dynamics (Flint et al. 1998) and funding was adequate to study only one sex (sample size had to be sufficient for other study objectives [e.g., survival estimation]). Our goals were to: 1) document distribution patterns and determine day and night habitat use and selection during Prehunt, Hunt, and Posthunt; 2) identify the relative importance of roosting and feeding habitats for pintails in the MWA; and 3) test the null hypothesis that use of each habitat would equal its availability.

STUDY AREA

MWA is comprised of approximately 2,600 ha of wetlands open to waterfowl hunting and a 364-ha sanctuary (Fig. 2) (Fleskes[2] 1999). Most marsh is seasonal and is dry during summer except for periodic irrigations delivered via a series of interconnected ditches to promote seed production of watergrass, *Echinochloa crusgalli*, swamp timothy, *Heleochloa schoenoides*, pricklegrass, *Crypsis niliaca*, (a species similar to swamp timothy), and other wetland plants. Additional water is delivered to flood marshes starting in mid-August, so most are fully flooded by the start of waterfowl hunting season. Periodic water deliveries and late-winter rains maintain water levels in marshes throughout hunting season. After hunting season, water is drained from marshes to allow wetland plants to germinate.

Duck hunting daily bag limits and season lengths remained constant during the study, but the timing of Hunt varied among years. For 1991, 1992, and 1993, respectively, Hunt was composed of a 22-day first season starting 26, 24, or 23 October, a 12-, 19-, or 27-day closure that split the duck hunting season, and a 37-day second season ending 5, 10, or 16 January (California Department of Fish and Game[3] 1991, California Department of Fish and Game[4] 1992, California Department of Fish and Game[5] 1993). MWA allowed hunting only on Wednesdays, Saturdays, and Sundays during Hunt (hereafter shoot days). We define Posthunt as the interval from

[2]Fleskes, J. P. 1999. Ecology of female northern pintails during winter in the San Joaquin Valley, California. Dissertation, Oregon State University, Corvallis, Oregon, USA.

[3]California Department of Fish and Game. 1991. 1991 California hunting regulations: Parts II and III. Resident and migratory game birds. California Department of Fish and Game, Sacramento, California, USA.

[4]California Department of Fish and Game. 1992. 1992 California hunting regulations: Parts II and III. Resident and migratory game birds. California Department of Fish and Game, Sacramento, California, USA.

[5]California Department of Fish and Game. 1993. 1993 California hunting regulations: Parts II and III. Resident and migratory game birds. California Department of Fish and Game, Sacramento, California, USA.

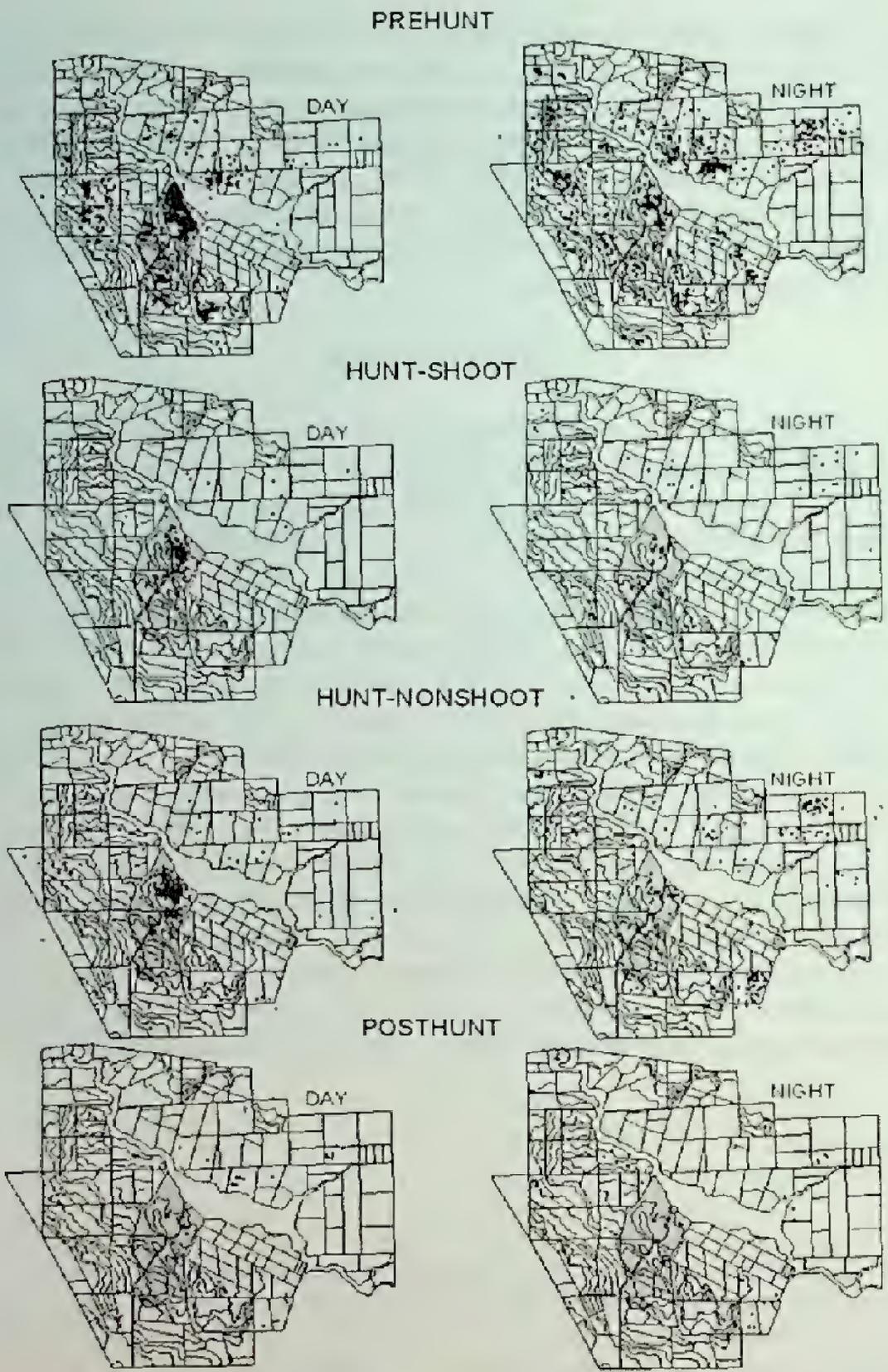

Figure 2. Day and night locations (points) of radio-tagged female northern pintails, *Anas acuta*, in the Mendota Wildlife Area before (prehunt), on shoot (Wednesdays and weekends) and nonshoot days during (hunt), and after (posthunt) the duck hunting season, 1991-94. Duck hunting was not allowed in the shaded marsh units (sanctuary) but was allowed in the lake (large central unit oriented northwest-southeast on the north border of the sanctuary) and all the other units.

end of Hunt to 1 April 1992 and 1993 or 17 March 1994.

METHODS

Classifying Habitat

We observed no pintails using dry lands (except levees, shorelines, islands) in the San Joaquin Valley and considered only flooded areas as potential pintail habitat. We classified flooded areas three ways based upon: 1) hydrology and physical characteristics, 2) vegetation composition, and 3) percent emergent cover.

MWA was composed of a mostly open central lake and numerous more shallow marsh units (Fig. 2). Vegetation and weekly flooding data were mapped for each unit by a MWA biologist. Based upon the dominant understory vegetation, we classified the MWA marsh units (excluding the lake) and three privately-held in-holding marsh units as: 1) swamp timothy (includes pricklegrass); 2) watergrass (usually associated with sprangletop, *Leptochloa* spp.); 3) alkali bulrush, *Scirpus paludosus*; 4) upland plants; and 5) other (primarily *Juncus* spp., *Paspalum distichum*, *Polygonum* spp.). We further classified marsh units (excluding the lake) with <25% of surface area with emergent vegetation (i.e. *Typhus* sp., *Juncus* spp., etc.) as "open", 25-75% as "hemi" and ≥76% as "closed".

Measuring Habitat Availability

To represent the average amount of each habitat type that was available to the radio-tagged pintails in the MWA during the multi-week Prehunt, Hunt, and Posthunt intervals (i.e., habitat availability), we weighted weekly estimates of the amount of flooded area of each habitat by the number of pintail locations we obtained that week and then calculated each interval average. First, we entered vegetation and weekly flooding data into a Geographic Information System (GIS) and ARC/INFO (ESRI) computer program. Next, we used the data in the GIS to determine flooded area of each habitat each week in the MWA during August-March, 1991-94. Finally, because the number of radio-tagged pintails present in the MWA changed each week due to emigration, immigration, and mortality, rather than simply averaging weekly flooding estimates to calculate average flooded area of each habitat for the multi-week Prehunt, Hunt, and Posthunt intervals, we instead weighted weekly flooding estimates by the number of pintail locations obtained in the MWA that week and then calculated interval averages. We estimated availability and use for the three multi-week intervals rather than individual weeks because the number of locations we obtained per week for each pintail was inadequate for weekly comparisons of use and availability. Also, although flooding did change somewhat among weeks within intervals (especially as marshes were flooded during Prehunt), flooding and pintail movement patterns within intervals were more similar than across intervals. Weighting weekly flooding estimates by the number of pintail locations that week to calculate interval averages avoided potential bias in comparisons of habitat availability and use by our radio-

tagged sample of pintails. For instance, suppose timothy units comprised a greater proportion of total flooded habitat during the first few weeks of Prehunt, when few radio-tagged pintails were present because we had not yet radio tagged our entire sample, than during the later weeks of Prehunt, by which time the entire radio-tagged sample of pintails were at Mendota WA. Then calculating an average availability of timothy during Prehunt without weighting weekly flooding estimates by our weekly sample size would over-estimate the true percentage of total habitat comprised by timothy that was available on average during Prehunt to an average radio-tagged pintail. This hypothetical over-representation of actual timothy availability would result in a bias against finding selection of timothy by pintails in the comparison of habitat use vs. availability during Prehunt.

Measuring Habitat Use

Pintail Capture and Tracking

We periodically pinpointed locations of 145 radio-tagged female pintails (n = 30 in 1991-92, 30 in 1992-93, and 85 in 1993-94) to track their habitat use in the MWA during September through late March, 1991-94. We studied MWA habitat use of all 46 Hatch-Year (HY) and 70 After-Hatch-Year (AHY) pintails that we radio tagged in MWA, 5 HY and 8 AHY pintails that we radio tagged in the Grassland Ecological Area, 7 HY and 7 AHY pintails that we radio tagged in post-harvest flooded fields near Kern NWR, and 1 AHY and 1 HY pintails that Casazza[6] (1995) radio tagged in Suisun Marsh (Fig. 1). Pintails were captured with rocket-nets (Schemnitz 1994) during 29 August - 6 October 1991, 31 August - 5 October 1992, and 28 August - 25 September 1993. Captured pintails were aged (Carney[7] 1992), weighed (± 5 g), measured (flat wing, culmen 1, total tarsus [Dzubin and Cooch[8] 1992]), radio tagged (Dwyer 1972, Pietz et al. 1995), and released at the capture site.

We scanned the MWA entirely from trucks and aircraft (Gilmer et al. 1981) and determined each pintail's location on ≥2 shoot days and following nights and ≥2 nonshoot days and following nights each week during Hunt and ≥2 days and nights each week during Prehunt and Posthunt. We obtained two bearings from known locations using a truck-mounted dual-Yagi null-peak telemetry system (Cochran and Lord 1963) to minimize time between bearings and because preliminary tests showed more bearings did not increase accuracy in our flat, open study areas. We obtained >89% of locations <1.6 km from the bird at 50-130 degree angles. Warnock and Takekawa (1995) reported an average azimuth error of 1.5 degrees and an error

[6]Casazza, M. L. 1995. Habitat use and movements of northern pintails wintering in the Suisun Marsh, California. Thesis, California State University, Sacramento, California, USA

[7]Carney, S. M. 1992. Species, age and sex identification of ducks using wing plumage. U.S. Fish and Wildlife Service, Washington, D. C., USA.

[8]Dzubin, A., and E. G. Cooch. 1992. Measurement of geese: general field methods. California Waterfowl Association. Sacramento, California, USA.

polygon of 1.1 ha with location distances 0.5-3.0 km using an identical system, which is much smaller than the average size of habitat polygons ($\bar{x}$ = 17.2 ha) in the MWA. We calculated pintail locations using a modified version of XYLOG and UTMTEL (Dodge et al.[9] 1986, Dodge and Steiner 1986). We intersected pintail locations in the GIS with digitized habitat maps to determine habitat for each location.

Habitat Selection Analysis

We used compositional analysis (Aitchison 1986, Aebischer et al. 1993) to examine day and night habitat selection by pintails. We considered all flooded areas in the MWA available for potential use by each pintail in the MWA because all flooding was well within the daily pintail flight range from major pintail roost sites in the MWA (Fleskes[2] 1999). We used multivariate analysis of variance (Johnson and Wichern 1982, SAS Institute 1989) to test whether a composition of use-to-availability log ratios differed significantly from zero ($P \leq 0.05$), indicating selection by pintails. When selection was detected, ranks were assigned to each habitat type, means and standard errors for each log-ratio were calculated, and *t*-tests were used to identify significant ($P \leq 0.05$) differences among rankings of habitats (Aebischer et al. 1993). We compared habitat selection among years (1991-92, 1992-93, 1993-94), shoot and nonshoot days during hunting season, bird age class (HY, AHY), and bird capture mass (above vs. below age-class mean).

RESULTS

Habitat Area

Area of flooded habitat differed among intervals but was similar among study years (Table 1). The average area of flooded marsh was 2-3 times greater during Hunt and Posthunt than during the Prehunt interval. Despite annual variation in precipitation (California Department of Water Resources[10] 1991, National Oceanic and Atmospheric Administration, Asheville, North Carolina, USA, unpublished data), water supplies to flood MWA marshes were consistently available during the study. Thus, unlike in other parts of the San Joaquin Valley (Fleskes[2] 1999), area of waterfowl habitat at MWA was similar among study years. A weekly average of 949-1,256 ha of shallow marsh was flooded during Prehunt and 2,565-2,762 ha of shallow marsh was flooded during Hunt and Posthunt; area of the slighty deeper lake in the center of MWA ranged

[9]Dodge, W. E., D. S. Wilkie, and A. J. Steiner. 1986. UTMTEL: A laptop computer program for location of telemetry "finds" using Loran-C. Massachusetts Cooperative Research Unit. Report, U.S. Fish and Wildlife Service.

[10]California Department of Water Resources. 1991. California's continuing drought, 1987-1991: A summary of impacts and conditions as of December 1, 1991. Sacramento, California, USA.

Table 1. Mean weekly flooded hectares of lake and marsh habitat at Mendota Wildlife Area during Prehunt, Hunt, and Posthunt, 1991-94. Flooded hectares of marsh (i.e., excluding the lake) where swamp timothy (T), watergrass (W), alkali bulrush (A), other wetland (O), or upland (U) plants were the dominant plants and by emergent cover (<25% open, ≥25-75% hemi, >75% closed) are also presented.

	PREHUNT			HUNT			POSTHUNT		
Habitat	1991-92	1992-93	1993-94	1991-92	1992-93	1993-94	1991-92	1992-93	1993-94
Lake	364	364	364	364	364	337	364	364	269
Marsh	1,256	949	1,075	2,568	2,593	2,762	2,565	2,672	2,610
T	857	686	686	1,763	1,726	1,699	1,771	1,735	1,622
W	87	66	154	261	386	539	268	423	573
A	60	15	20	83	22	20	69	15	10
O	224	154	163	401	357	310	412	336	235
U	28	28	52	60	102	194	45	163	170
Open	732	627	815	1,711	1,994	2,244	1,721	2,088	2,150
Hemi	437	250	201	766	501	429	746	486	395
Closed	87	72	59	91	98	89	98	98	65

between 269 ha and 364 ha (Table 1).

General Patterns of Use

Distribution and movement patterns of pintails within MWA varied by season. During Prehunt, pintail distribution generally tracked flooding of marsh units although their distribution was more concentrated during the day and more dispersed within and among units at night (Fig. 2). During Hunt, the few pintails that did not leave MWA dispersed throughout the area at night but mostly returned to the sanctuary units on both shoot and nonshoot days. The few pintails present during Posthunt dispersed throughout MWA during both day and night (Fig. 2)

Use and Selection of the Lake vs. Marsh Units

Although the lake in the center of MWA comprised 11-20% of the average weekly flooded area there, female pintails avoided it in favor of the marsh units throughout the rest of the area ($t \geq 21.70$, $P < 0.001$). Except for Posthunt nights, ≤1% of pintail locations were ever in the lake (Table 2).

Use and Selection of Marsh by Dominant Understory Plant

Swamp timothy marsh received more pintail use than any other marsh type comprising 65-71% of the marsh available and receiving 63-91% of the use by pintails (Table 2). Pintail use of watergrass marsh was greater at night than during day and greater during Hunt and Posthunt than during Prehunt (Table 2). Female pintails selected timothy marsh during all intervals; watergrass marsh was avoided during the day, but along with timothy marsh, was selected at night during most years (Table 3). Selection of flooded marsh where upland plants, alkali bulrush, or other "non-timothy or watergrass" plants were primary understory plants ranked in the middle during the day but was avoided at night during most intervals and years. Selection strength differed among years and between shoot and nonshoot dates but rankings were similar (Table 3).

Use and Selection of Open vs. Hemi vs. Closed Marsh

Use and selection of marsh by the percentage of emergent cover varied. Closed marsh comprised ≤5% of the available marsh but received 27% of the use during day during Prehunt and 26% during Hunt; use of closed marsh was minimal at night in all seasons and during Posthunt days (Table 2). Pintails selected open and avoided closed marsh at night; selection during the day varied among seasons and years (Table 3). During Prehunt days, open marsh was selected in 1991 and 1992 but closed marsh was selected in 1993. During Hunt days, closed or hemi marsh was selected. During Posthunt days, open marsh was selected.

Selection Relative to Pintail Body Mass and Age

Table 2. Composition (proportions) of wetland types (lake, marsh), marsh by dominant plant (swamp timothy [T], watergrass [W], alkali bulrush [A], other wetland [O], or upland [U] plants), and marsh by emergent cover (<25% open, ≥25-75% hemi, >75% closed) that was available (Avail = x̄ of weekly proportions weighted by number of pintail locations) and used during prehunt, hunt, and posthunt days and nights by 145 radio-tagged female northern pintails, *Anas acuta*, at Mendota Wildlife Area, 1991-94.

	PREHUNT			HUNT			POSTHUNT		
Habitat	Avail	Day use	Night use	Avail	Day use	Night use	Avail	Day use	Night use
Lake	0.20	<0.01	<0.01	0.12	<0.01	0.01	0.11	<0.01	0.08
Marsh	0.80	>0.99	>0.99	0.88	>0.99	0.99	0.89	>0.99	0.92
T	0.71	0.91	0.86	0.66	0.90	0.69	0.65	0.87	0.63
W	0.10	0.01	0.05	0.14	0.02	0.24	0.16	0.11	0.32
A	0.02	<0.01	<0.01	0.02	<0.01	<0.01	0.01	<0.01	<0.01
O	0.15	0.08	0.08	0.14	0.06	0.06	0.13	<0.01	0.03
U	0.02	0.01	0.01	0.04	0.01	0.01	0.05	0.03	0.01
Open	0.70	0.51	0.73	0.74	0.42	0.76	0.76	0.93	0.88
Hemi	0.25	0.22	0.20	0.22	0.32	0.22	0.21	0.07	0.12
Closed	0.05	0.27	0.07	0.04	0.26	0.02	0.03	<0.01	<0.01

Table 3. Selection by radio-tagged female northern pintails, *Anas acuta*, of marshes classified by dominant vegetation (swamp timothy [T], watergrass [W], alkali bulrush [A], other wetland [O], upland plants [U]) and emergent cover (<25% open, 25-75% hemi, >75% closed) at Mendota Wildlife Area, California, during prehunt (Pre), hunt (Hnt) and posthunt (Pos) days (D) and nights (N), 1991-94.

Comparison[a]					Ranking[b] by dominant plant					Ranking by % cover		
Interval	n	Year	Age	Shoot Status	T	W	A	O	U	open	hemi	closed
PreD	131	Pooled	Pooled	Nonshoot	1A	5C	2B	3B	4B	3B	2B	1A
	28	1991-92	Pooled	Nonshoot	1A	5D	4D	2B	3C	1A	2A	3A
	27	1992-93	Pooled	Nonshoot	1A	5D	3C	2B	4CD	1A	2B	3B
	76	1993-94	Pooled	Nonshoot	1A	5C	2B	4C	3B	3C	2B	1A
	80	Pooled	HY	Nonshoot						3B	2B	1A
	51	Pooled	AHY	Nonshoot						2A	3A	1A
PreN	131	Pooled	Pooled	Nonshoot	1A	2B	4B	3B	5B	1A	2B	3C
HntD	70	Pooled	Pooled	Pooled	1A	5D	2B	4C	3C	3B	2A	1A
	17	1991-92	Pooled	Pooled	1A	5C	4BC	3BC	2B	2AB	3B	1A
	13	1992-93	Pooled	Pooled	1A	5C	2B	4BC	3B	3A	2A	1A
	40	1993-94	Pooled	Pooled	1A	5C	2B	4C	3C	3B	1A	2AB
HntN	57	Pooled	Pooled	Pooled	1A	2B	4B	3B	5B	1A	2B	3B
	13	1991-92	Pooled	Pooled	1A	2AB	4BC	5C	3B	1A	2AB	3B
	11	1992-93	Pooled	Pooled	1A	4B	2B	3B	5B	1A	2A	3B
	33	1993-94	Pooled	Pooled	1A	2A	3B	4C	5C	1A	3C	2B
	26	Pooled	Pooled	Shoot	1A	3B	2B	5C	4B			
	51	Pooled	Pooled	Nonshoot	1A	2A	3B	4C	5C			
PosD	12	Pooled	Pooled	Nonshoot	1A	3B	2B	5B	4B	1A	2B	3B
PosN	8	Pooled	Pooled	Nonshoot	2A	1A	4B	4B	5B	1A	2AB	3B

[a]Comparisons listed by year, pintail age or shoot status only when rankings for that variable differed (Wilks' Lambda test, $P < 0.05$), rankings for pintails with different body condition did not differ.

[b]Rankings with same letters not different (t-test, $P < 0.05$).

Habitat rankings were nearly identical for HY and AHY pintails. Pintail age appeared as a significant factor in habitat selection models in only one instance when use rankings of Hemi and Open marsh during Prehunt differed by age (Table 3). Habitat selection did not differ among pintails that were lighter or heavier than average at capture.

DISCUSSION

Foraging Habitats Selection

All but a few pintail locations were in marsh units rather than the lake. We speculate this was because the lake produced fewer seeds preferred by pintails and was too deep for pintails to tip-up and forage for seeds in the lake bottom. Our finding that foraging pintails used and selected both swamp timothy and watergrass marsh at MWA is consistent with pintail food habits (Beam and Gruenhagen[11] 1980, Connelly and Chesemore 1980) and habitat use reported for other San Joaquin Valley areas (Euliss and Harris 1987). However, in contrast to the high night use of watergrass marsh by pintails that we observed at MWA and was reported for pintails at Kern NWR (Euliss and Harris 1987), pintails in the Grassland Ecological Area mostly avoided watergrass marsh at night (Fleskes et al. 2004). We speculate that watergrass fields were more attractive to feeding pintails at MWA than in the Grassland Ecological Area because watergrass fields at MWA were drained earlier and allowed to dry before reflooding (G. Gerstenberg, California Department of Fish and Game, Los Banos, California, USA, personal communication), resulting in shorter, less dense stands with seeds that ripen and disperse when reflooded. Alternatively, with fewer mallards, *Anas platyrhynchos*, at MWA than in the Grassland Ecological Area (California Department of Fish and Game, Sacramento, California, unpublished data), pintails may have faced less competition in watergrass marsh at MWA than in the Grassland Ecological Area allowing increased pintail use of watergrass at MWA.

Roosting Habitat Selection

Pintails roosted in or near feeding marshes during all Posthunt periods but selected closed or hemi-marsh on Hunt days and some Prehunt days. The need to avoid disturbance is a major factor in roost selection (Wolder[12] 1993) and we speculate that pintails avoided the mostly open water lake and open marsh units and sought isolation in vegetated marshes to avoid disturbance from hunters, fishermen, water managers,

[11]Beam, J., and N. Gruenhagen. 1980. Feeding ecology of pintails (*Anas acuta*) wintering on the Los Banos Wildlife Area, Merced County, California. California Department of Fish and Game, Federal Aid Wildlife Restoration Progress Report, Project W-40-D-1.

[12]Wolder, M. A. 1993. Disturbance of wintering northern pintails at Sacramento National Wildlife Refuge, California. Thesis, Humboldt State University, Arcata, California, USA.

and others that was greatest during Hunt and some Prehunt days.

MANAGEMENT IMPLICATIONS

Major (e.g., 95% of radio-tagged pintails) exodus of pintails from MWA each fall coinciding with the start of hunting season indicates that disturbance associated with hunting made MWA less attractive to pintails than areas to the north where most pintails went (Fleskes et al. 2002b). Cox and Afton (1998) reported low pintail use of 12 Louisiana sanctuaries 137 ha to 2,514 ha in size and cited placement of sanctuaries in areas with few pintails, late flooding, dense vegetation, and small size of sanctuaries as reasons for low use by pintails. The MWA sanctuary was surrounded by >2,500 ha of flooded marsh and both the sanctuary and surrounding wetlands were flooded during Prehunt and used extensively by pintails (Fig. 2), suggesting that its 364-ha size may have been the limiting factor. Although larger than the Merced NWR sanctuary that held large concentrations of pintails during the same years as this study, the MWA sanctuary was only half the total area of the San Luis NWR sanctuary, which was the main pintail roost area in the Grassland Ecological Area (Fleskes et al. 2002a, California Department of Fish and Game, unpublished data). Further, although roads open to the public surrounded and bisected sanctuaries on all three areas, road traffic or some aspect of its management resulted in few pintails using the southern half of the MWA sanctuary during the hunting season (Fig. 2), effectively halving its functional size. Thus, any effort to reduce exodus of pintails from MWA should first focus on why the southern part of the sanctuary received little use by pintails.

Pintails concentrated in sanctuary units not only on shoot days but also on nonshoot days during Hunt and in some instances selected closed marsh even during Prehunt days. This indicates that disturbance impacting pintail use of habitats at MWA was not limited to hunting. Many roads on MWA are open to the public during Prehunt for fishing and dove hunting and some are open to the public on nonshoot days during Hunt. In addition, flooding and maintenance of units require frequent monitoring by managers.

The management and layout of MWA provides an attractive landscape for pintails during Prehunt but habitat requirements of pintails are apparently not being met thereafter. Although it is possible that depleted food supplies contributed to pintails leaving MWA, the fact most departed during the first few days of hunting season indicates disturbance was the main factor. Thus, to increase the percentage of pintails that stay beyond the first week of Hunt, management should not only continue to emphasize shallow (i.e., ≤30 cm, Isola et al. 2000) preferred feeding habitats such as watergrass (as managed at MWA) and timothy marsh but also reduce disturbance and increase functional sanctuary.

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improved all aspects of this project. Steve Brueggemann, a MWA biologist, mapped vegetation and weekly flooding data for each unit. San Luis and Kern NWRs, and Mendota and Los Banos Wildlife Areas provided housing or logistical support. Nearly all landowners we contacted permitted trapping or tracking access and nearly all hunters reported and provided information about pintails they recovered. M. Carriere of Busch Agriculture donated rice for trapping. L. Belt, D. Breneman, D. Buford, M. Chouinard, Jr., C. Davis, R. Dunston, M. Humpert, P. Johnston, J. Laffitte, K. Mazacco, C. Stemler, and K. Young trapped and tracked pintails. California Department of Fish and Game donated aerial search costs. C. Fleskes, K. Lee, and G. Martinelli entered habitat data and W. Perry and J. Daugherty provided GIS support. J. L. Lee provided extensive statistical support. K. Hashagen, C. Hildebrandt, R. Holbrook, and D. Orthmeyer provided comments that improved the manuscript.

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A SIMPLE ONE-WAY DOOR DESIGN FOR PASSIVE RELOCATION OF WESTERN BURROWING OWLS

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California supports a declining population of resident and migratory Western Burrowing Owls, *Athene cunicularia hypugaea*, which occur in grasslands throughout the State. Primary causes of population declines in California are conversion of grassland habitats to agriculture or urban land uses and eradication of fossorial mammals, such as the California ground squirrel (*Spermophilus beecheyi*; Haug et al. 1993). The Burrowing Owl, identified as a species of special concern by the California Department of Fish and Game, appropriates burrows made by other animals. Burrowing Owls usually do not excavate their own burrows. Burrowing Owls also require open grassland fields with a sufficient food supply for foraging habitat, low vegetative cover to allow owls to watch for predators, and adequate roosting sites (Zarn 1974). The owl is protected under the Migratory Bird treaty Act of 1918 (16 U.S.C. 703-712; Ch. 128; July 13, 1918; 40 Stat. 755, as amended), which prohibits the destruction of owls or their nests. California Fish and Game Code (sections 3503, 3503.5, 3513, 3800-3806) also protects these owls, their nests, eggs, and young (LawTech Publishing 2004). When economic development or other land conversion is planned where these owls occur, the California Department of Fish and Game often suggests mitigation for the destruction of burrows during development projects, or similar activities.

The California Burrowing Owl Consortium (CBOC 1993)[2] developed a Survey Protocol and Mitigation Guideline to meet the need for standardized measures when surveying Burrowing Owl populations, and for evaluating impacts to owl habitat from development projects. The guidelines were "intended to provide a decision-making process that should be implemented wherever there is potential for an action or project to adversely affect burrowing owls or the resources that support them" (CBOC 1993)[2], and were submitted for consideration by the California Department of Fish and Game. The California Department of Fish and Game adapted these suggested guidelines in its

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[2] California Burrowing Owl Consortium (CBOC). 1993. Burrowing owl survey protocol and mitigation guidelines. Technical Report, Burrowing Owl Consortium, Alviso, California.

own report (CDFG 1995)[3]. Trulio (1995) described one approach to mitigating Burrowing Owl habitat loss due to development: passive relocation. On-site passive relocation should be implemented if other avoidance requirements cannot be met (see CBOC 1993)[2]. Passive relocation was defined as "encouraging owls to move from occupied burrows to alternate natural or artificial burrows that are beyond 50 m from the impact zone and that are within or contiguous to a minimum of 6.5 acres of foraging habitat for each pair of relocated owls" (CBOC 1993)[2]. Relocation of owls should be implemented during the non-breeding season, however occupied burrows can be disturbed during the nesting season (February 1 through August 31) if a qualified biologist approved by the California Department of Fish and Game verifies through non-invasive methods either: the owls have not begun egg-laying and incubation, or that juveniles from the occupied burrows are foraging independently and are capable of independent survival (CDFG 1995)[3].

Trulio (1995) described passive relation of owls in terms of using artificial burrows. Following the guidelines established by the California Burrowing Owl Consortium (1993)[2], the passive relocation process is composed of four phases: impact assessment, artificial burrow creation, owl eviction, and monitoring. Trulio (1995) described the process in significant detail, and therefore is not expanded upon here. However, both the California Burrowing Owl Consortium (1993)[2] and Trulio (1995) call for one-way doors to be used as a method to exclude owls from an occupied burrow and not allow them to re-enter the burrow. No guidance is provided for an effective one-way door design that is simple to manufacture, inexpensive, and can be employed in large numbers depending on the size of the development. Here we describe a field-tested design that fits the criteria recommended by the California Burrowing Owl Consortium (1993)[2] and Trulio (1995). The design was field-tested in several economic development / land conversion projects where passive relocation of owls was necessary. Several hundred owls were successfully passively relocated from over 20 projects from 1997-2004 throughout California, including the San Joaquin Valley, San Francisco Bay area, and the Dublin area in Alameda County (H. T. Harvey & Associates, unpublished data). The owls showed no apprehension in exiting the one-way doors (S. Terrill, H. T. Harvey & Associates, personal communication).

The one-way door is a variation of the Burrowing Owl trap theme described in Martin (1971), Plumpton and Lutz (1992), and Botelho and Arrowood (1995), among many others. These traps are humane, safe, and will not cause injury to the bird. The main difference is the one-way door does not trap the owl – it excluded the owl from a burrow once the owl has exited the one-way door device. The one-way door design described herein is modified from a readily available dryer vent (Figure 1 — Deflecto® 4 inch Supurr-Vent® louvered vent hood with aluminum pipe, model number SVHAW4, Deflecto Corporation, Indianapolis, Indiana).

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[3] California Department of Fish and Game (CDFG). 1995. Staff Report on Burrowing Owl Mitigation. Unpublished report. 8 pp. Report dated 25 Sep 1995. California Department of Fish and Game, Sacramento, California.

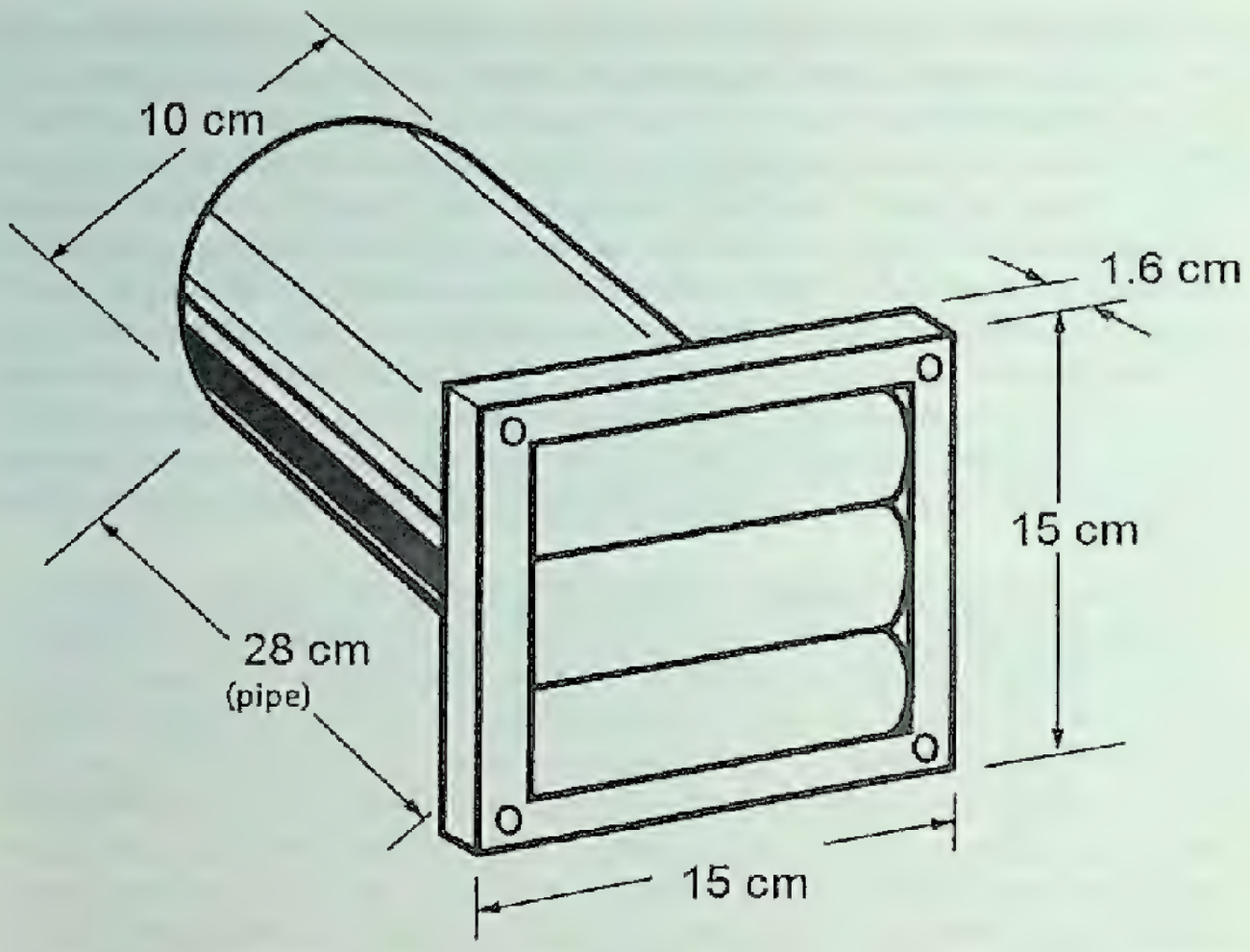

Figure 1. Deflecto® 4 in dryer vent, Supurr-Vent® louvered vent hood with aluminum pipe, model number SVHAW4.

The vent hood has three louvers (Figure 2). The two lower louvers are removed, while the upper louver remains in place. Rivet to the upper louver a 7 x 10 cm piece of Plexiglas (or some other thin, rigid, transparent plastic material). The Plexiglas allows the owl to see through the door and exit the tube. The owls may further be encouraged to use the one-way door by spraying the inside of the tube with spray adhesive and sprinkling a coat of sand on the inside of the tube while the spray adhesive is still wet. The sand provides a footing for the owl upon exiting the one-way door device. The one-way doors should be left over the burrow entrance 3-4 days (Trulio 1995). The previously occupied burrow should be carefully excavated and collapsed as described in Trulio (1995).

Once the one-way doors are removed they can be reused and employed elsewhere. The design is effective in projects with similarly sized small mammal burrows as well as in areas with a substantial small mammal population with a variety of non-uniformed burrow opening configurations (H. T. Harvey & Associates, unpublished data). The design is simple, inexpensive, and can be manufactured in large qualities in a short period of time with minimal materials and tools.

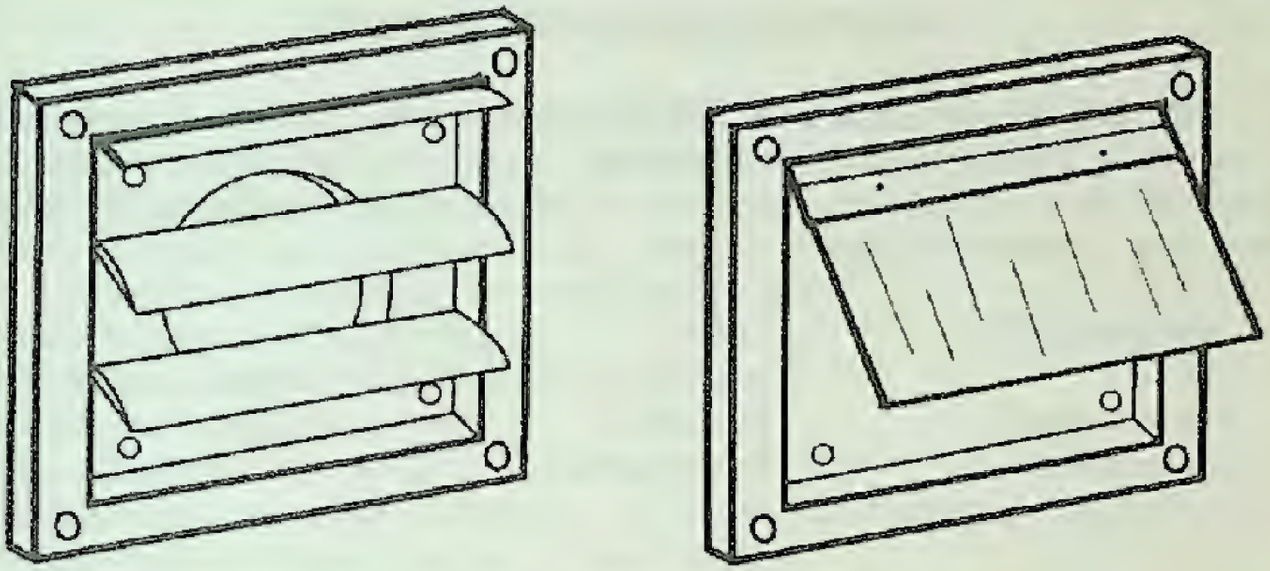

Figure 2. The vent hood has three louvers. The two lower louvers are removed, while the upper louver remains in place. Rivet to the upper louver a 7 x 10 cm piece of Plexiglas. Plexiglas riveted to the upper louver becomes the one-way door.

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California Fish and Game 91(4):291-300 2005

INDEX TO VOLUME 91 (2005)

AUTHORS

Alpers, Charles N., see Saiki et al.
Becker, Gordon: see Leidy, Becker, and Harvey
Bjurstrom, Kalen Z.: see Hosea, Bjurstrom, and Littrell
Bleich, Vernon C.: see Oehler et al.
Bleich, Vernon C.: see Wehausen, Bleich, and Ramey
Bowyer, R. Terry: see Oehler et al.
Chinn, Zachary K. J.: see Pondella and Chinn
Clark, Howard O., and David L. Plumpton: A Simple One-Way Door Design for Passive Relocation of Western Burrowing Owls, 309 - 312.
Dial, Roman: see McGrann, McGrann, and Dial
Dickert, Catherine: Giant Garter Snake Surveys at Some Areas of Historical Occupation in the Grasslands Ecological Area, Merced Co, and Mendota Wildlife Area, Fresno Co., California, 255 - 269.
Fire, Spencer E. and Mary W. Silver: Domoic Acid in the Santa Cruz Wharf Fishery, 179 - 192.
Fleskes, Joseph P., David S. Gilmer, and Robert L. Jarvis: Pintail Distribution and Selection of Marsh Types at Mendota Wildlife Area During Fall and Winter, 270-286.
Fleskes, Joseph P., William Perry, Kevin Petrik, Futh Spell, and Fritz Reid: Change in Area of Winter-Flooded and Dry Rice in the Northern Central Valley of California Determined by Satellite Imagery, 297 - 315
Franklin, Michael P.: see Miller and Franklin
Garrison, Barrett A., Robin L. Wachs, and Matthew L Triggs: Response of Forest Squirrels to Group-Selection Timber Harvesting in the Central Sierra Nevada, 1-20.
Geibel, John J.: see Gotshall and Geibel
Gilmer, David S.: see Fleskes, Gilmer, and Jarvis
Gotshall, Daniel W. and John J. Geibel: Fish By-Catch in Dungeness Crab, Cancer magister, Research Trawls Off Northern California, 1966-1969, 21-37.
Harvey, Brett N.: see Leidy, Becker, and Harvey
Hosea, Robert C., Kalen Z. Bjurstrom, and Edward E. Littrell: Acute Oral and Dermal Toxicity of Aquatic Herbicides and a Surfactant to Garter Snakes, 119 - 127
Jarvis, Robert L.: see Fleskes, Gilmer, and Jarvis
Keifer, Shane J. and Floyd W. Weckerly: Population Density and Body Weight Influences on Home Range Size of Feral Hogs, 136 - 142
Leidy, Robert A., Gordon Becker, and Brett N. Harvey: Historical Status of Coho Salmon in Streams of the Urbanized San Francisco Estuary, California, 219 - 254.
Littrell, Edward E.: see Hosea, Bjurstrom, and Littrell
Markle, Douglas F.: see Remple and Markle
Martin, Barbara A, : see Saiki et al.

Matica, Zoltan and Matt Nobriga: Modifications to an Agricultural Water Diversion to Permit Fish Entrainment Sampling, 53-56.
May, Thomas W.: see Saiki et al.
McGrann, Amy M., Michael C. McGrann, and Roman Dial: Off-Highway Vehicle Impact on *Astragalus magdalenae* var. *peirsonii*, and Other Critical Plant Species of the Algodones Dunes, California, 61-82
McGrann, Michael C.: see McGrann, McGrann, and Dial
Miller, Eric F. and Michael P Franklin: The Effect of Dietary Supplemented L-Arginine on the Growth of Juvenile Hatchery Reared White Seabass, Atractoscion nobilis, 47-52.
Nicholson, Matthew C.: see Oehler et al.
Nobriga, Matt: see Matica and Nobriga
Oehler, Michael W., Sr, Vernon C. Bleich, R. Terry Bowyer, and Matthew C. Nicholson: Mountain Sheep and Mining: Implications for Conservation and Management, 149-178.
Perry, William M.: see Fleskes et al.
Petrik, Kevin L., see Fleskes et al.
Pondella, Daniel J., III, and Zachary K. J. Chinn: Records of Chameleon Goby, *Tridentiger trigonocephalus*, in San Diego Bay, California, 57-59.
Ramey, Rob R., II: see Wehausen, Bleich, and Ramey
Reid, Fritz: see Fleskes et al.
Remple, Stacy and Douglas F. Markle: Description and Identification of Larval and Juvenile Cyprinids (Fathead Minnow, Tui Chub, and Blue Chub) From Upper Klamath Lake, Oregon, 83-99
Richter, David J.: Territory Occupancy, Reproductive Success, and Nest Site Characteristics of Goshawks on Managed Timberlands in Central and Northern California 1993-2000, 100-118
Saiki, Michael K., Barbara A. Martin, Thomas W. May, and Charles N. Alpers: Total Mercury Concentrations in Fillets of Bluegill, Redear Sunfish, Largemouth Bass, and Other Fishes from Lake Natoma, Sacramento County, California, 193-206
Silver, Mary W.: see Fire and Silver
Smith Susan E.: Leopard Shark Mating Observed Off La Jolla, California, 128-135
Spell, Ruth: see Fleskes et al.
Spina, Anthony P.: A Protective Housing for Instream Data Temperature Loggers, 143-147
Triggs, Matthew L.: see Garrison, Wachs, and Triggs
Trumbo, Joel: An Assessment of the Hazard of a Mixture of the Herbicide Rodeo and the Non-Ionic Surfactant R-11 to Aquatic Invertebrates and Larval Amphibians, 38-46.
Wachs, Robin L.: see Garrison, Wachs, and Triggs
Weckerly, Floyd W.: see Kiefer and Weckerly
Wehausen, John D., Vernon C. Bleich, and Rob R. Ramey II: Correct Nomenclature for Sierra Nevada Bighorn Sheep, 216-218

SUBJECT

Algodones Dunes, California: Off-Highway Vehicle Impact on *Astragalus magdalenae* var. *peirsonii*, and Other Critical Plant Species of the, 61 - 82

Amphibians, Larval: An Assessment of the Hazard of a Mixture of the Herbicide Rodeo and the Non-Ionic Surfactant R-11 to Aquatic Invertebrates and, 38-46.

Bighorn Sheep, Sierra Nevada: Correct Nomenclature for, 216 - 218

Burrowing Owl, Western: A Simple One-Way Door for Passive Relocation, 309 - 312

Coho Salmon: Historical Status of, in Streams of the Urbanized San Francisco Estuary, California, 219 - 254

Conservation: Mountain Sheep and Mining: Implications for, and Management, 149 - 178

Cyprinids, Larval and Juvenile: Description and Identification of, From Upper Klamath Lake, Oregon, 83 - 99

Distribution and Selection: Pintail, of Marsh Types at Mendota Wildlife Area During Fall and Winter, 270 - 285

Domoic Acid: in the Santa Cruz Wharf Fishery, 179 - 192

Dungeness Crab: Fish By-Catch in, Research Trawls Off Northern California 1966-1969, 21-37.

Fish By-Catch: In Dungeness Crab, Cancer magister, Research Trawls Off Northern California 1966-1969, 21-37.

Garter Snakes: Acute Oral and Dermal Toxicity of Aquatic Herbicides and a Surfactant on, 119 - 127

Giant Garter Snakes: Surveys at Some Areas of Historic Occupation in the Grasslands Ecological Area, Merced Co. and Mendota Wildlife Area, Fresno Co., California, 255 - 269

Goby, Chameleon: Records of, in San Diego Bay, California, 57-59.

Goshawks: Territory Occupancy, Reproductive Success, and Nest Site Characteristics of, on Managed Timberlands in Central and Northern California 1993 - 2000, 100 - 118

Herbicide: An Assessment of the Hazard of a Mixture of, Rodeo and the Non-Ionic Surfactant R-11 to Aquatic Invertebrates and Larval Amphibians, 38-46

Herbicides, Aquatic: Acute Oral and Dermal Toxicity of, and a Surfactant to Garter Snakes 119 - 127

Hogs, Feral: Population Density and Body Weight Influences on Home Range Size of, 136 - 142

Home Range Size: Populanton Density and Body Weight Influences on, of Feral Hogs, 136 - 142

Invertebrates, Aquatic: An Asssessment of the Hazard of a Mixture of the Herbicide Rodeo and the Non-Ionic Surfactant R-11 to, and Larval Amphibians, 38-46.

Klamath Lake, Upper: Description and Identification of Larval and Juvenile Cyprinids (Fathead Minnow, Tui Chub, and Blue Chub) From, 83 - 99

L-Arginine: The Effects of Dietary Supplemented, on the Growth of Juvenile Hatchery Reared White Seabass, *Atractoscion nobilis*, 47-52.

Management: Mountain Sheep and Mining: Implications for Conservation and, 149 - 178
Mecury, Total Concentrations: in Fillets of Bluegill, Redear Sunfish, Largemouth Bass, and Other Fishes from Lake Natoma, Sacramento County, California, 193 - 206
Mining: Mountain Sheep and,: Implications for Conservation and Management, 149 - 178
Mountain Sheep: and Mining, Implications for Conservation and Management, 149 - 178
Nest Site Characteristics: Reproductive Success, Territory Occupancy, and, of Goshawks on Managed Timberlands in Central and Northern California 1993 - 2000, 100 - 118
Nomenclature, Correct: for Sierra Nevada Bighorn Sheep, 216 - 218
Off-Highway Vehicle Impact: on *Astragalus magdelenae* var. *peirsonii*, and Other Critical Plant Species of the Algodones Dunes, California, 61 - 82
Pintail: Distribution and Selection of Marsh Types at Mendota Wildlife Area Duruing Fall and Winter, 270 - 285
Population Density and Body Weight Influences: on Home Range Size of Feral Hogs 136 - 142
Records: of Chameleon Goby, *Tridentiger trigonocephalus*, in San Diego Bay, California, 57-59.
Relocation, Passive: A Simple One-Way Door for, of Western Burrowing Owls, 309 - 312
Reproductive Success: Territory Occupancy, and Nest Site Characteristics of Goshawks on Managed Timberlands in Central and Northern California 1993 - 2000, 100 - 118
Research Trawls: Fish By-Catch in Dungeness Crab, *Cancer magister*, Off Northern California 1966-9169, 21-37.
Rice, Winter-Flooded and Dry: Change in Area of, in the Northern Central Valley of California, Determined by Satellite Imagery, 207 - 215
Sampling, Fish Entrainment: Modifications to an Agricultural Water Diversion to Permit, 53-56.
San Francisco Estuary: Historical Status of Coho Salmon in Streams of the Urbanized, 219 - 254
Satellite Imagery: Change in Winter-Flooded and Dry Rice in the Northern Central Valley of California, Determined by, 207 - 215
Seabass, White: The Effects of Dietary Supplemented L-Arginine on the Growth of Juvenile Hatchery Reared, 47-52.
Shark, Leopard: Mating Observed Off La Jolla, California 128 - 135
Squirrels, Forest: Responses to Group-Selection Timber Harvesting in the Central Sierra Nevada, 1-20.
Surveys: Giant Garter Snake, at Some Areas of Historic Occupation in the Grasslands Ecological Area, Merced Co. and Mendota Wildlife Area, Fresno Co., California, 255-269
Temperature Loggers: A Protective Housing For Instream Data, 143 - 147
Territory Occupancy: Reproductive Success, and Nest Site Characteristics of Goshawks on Managed Timberlands in Central and Northern California 1993 - 2000, 100 - 118

Timber Harvesting: Responses of Forest Squirrels to Group-Selection, in the Central Sierra Nevada, 1-20.
Toxicity, Acute Oral and Dermal: of Aquatic Herbicides and a Surfactant to Garter Snakes, 119 - 127
Water Diversion: Modifications to an Agricultural, to Permit Fish Entrainment Sampling, 53-56.

SCIENTIFIC NAMES

Abies concolor, 106
Abies concolor, 4
Abies magnifica, 106
Accipiter gentilis, 3, 100
Acipenser medirostris, 23
Acipenser transmontanus, 23
Agonopsis vulsa, 24
Allenrolfea occidentalis, 263
Allomerus elongatus, 23
Alnus rhombifolia, 229
Alosa sapidessima, 23
Ambrosia dumosa, 159
Ameiurus catus, 193
Ameiurus melas, 195
Ameiurus nebulosus, 193
Amphistichus rhodoterus, 24
Anas acuta, 271
Anas platyrhynchos, 282
Anoplopoma fimbria, 24
Arbutus menziesii, 107
Aristida glauca, 159
Armanda brevis, 189
Artedius harringtoni, 24
Asterotheca infraspinata, 24
Astragalus magdalenae var. *peirsonii*, 62
Athene cunicularia hypugaea, 309
Atheresthes stomias, 24
Atherinopsis californiensis, 185
Atractoscion nobilis, 47
Atriplex canescens, 151
Atriplex confertifolia, 154
Atriplex hymenelytra, 159
Bathyraja interrupta, 23
Bubo virginianus, 103
Calocedrus decurrens, 4, 107

Cancer magister, 21
Canis latrans, 154
Carassius auratus, 84, 121
Catostomus occidentails, 219
Ceanothus integerrimus, 4
Centaurea solstitialis, 260
Ceriodaphnia dubia, 38, 39, 44
Chamaebatia foliolosa, 4
Chilara taylori, 23
Citharichthys sordidus, 24
Clupea pattasi, 23
Coleogyne ramosissima, 154
Cololabis saira, 23
Conium maculatum, 265
Cottus asper, 219
Cottus gulosus, 219
Cryposis niliaca, 273
Cymatogaster aggregata, 24, 184
Cyprinus carpio, 84, 257
Dicentrarchus labrax, 48
Distichlis spicata, 263
Echinochloa cruzgallli, 270, 273
Eichhornia crassipes, 119
Embiotoca jacksoni, 185
Embiotoca lateralis, 185
Emerita analoga, 188
Encelia farinosa, 159
Engraulis mordax, 23, 180
Enteromorpha, 188
Ephedra nevadensis, 159
Eptatretus stouti, 23
Equus asinus, 154
Erigia densa, 119
Erigonum inflatum, 159
Erigonum rixfordii, 159
Eriogonum deserticola, 67
Eriogonum fasciculatum, 159
Eucyclogobius newberryi, 219
Galium stellatum, 159
Gambusia affinis, 121, 257
Gasterosteus aculeatus, 219
Genyonemus lineatus, 179, 184
Gila crassicauda, 257
Glaucomys volans, 15

Glyptocephalus zachirus, 24
Heleochloa schoenoides, 270, 273
Helianthus mives var. *tephrodes*, 62
Hemilepidotus hemilepidotus, 24
Hemilepidotus spinosus, 24
Hexagrammos decagrammus, 24
Hydrolagus colliei, 23
Hyperprosopon argenteum, 185
Hyperprosopon ellipticum, 24, 185
Hypomesus pretiosus, 23
Hypomesus transpacificus, 53
Icelinus tenuis, 24
Ictalurus sp., 257
Isopsetta isolepis, 24
Juncus sp., 260
Juncus spp., 275
Juniperus osteosperma, 154
Klamathella coerulea, 83
Lampetra tridentata, 219
Larrea tridentata, 154
Larus occidentalis, 131
Lavinia symetricus, 219
Lepidium latifolium, 260
Lepomis cyanellus, 195
Lepomis macrochirus, 193
Lepomis macrolophus, 193
Leptocottus armatus, 179, 184
Leptocottus armatus, 24
Liparis fucensis, 24
Liparis pulchellus, 24
Lycodes cortezianus, 24
Lycodes pacifica, 24
Lynx rufus, 154
Lyopsetta exilis, 24
Lyopsetta jordani, 24
Martes pennati, 3
Merluccius productus, 23
Microgadus proximus, 23
Micropterus dolomieu, 195
Micropterus punctulatus, 193
Micropterus salmoides, 193
Microstomus pacificus, 24
Morone saxatilis, 203
Mustelus henlei, 23

Myriophyllum aquaticum, 264
Mytilis edulis, 180
Notemigonus crysoleucas, 84
Occella verrucosa, 24
Odocoileus hemoinus, 154
Oncorhynchus kisutch, 219, 220, 240
Oncorhynchus mykiss, 53
Oncorhynchus mykiss, 193, 219
Oncorhynchus tschawytscha, 53, 227
Ophiodon elongatus, 24
Orthodon microlepidotus, 257
Ovis californianus, 216
Ovis canadensis, 149
Ovis cervina californiana, 216
Ovis cervina canadensis, 216
Ovis cervina nelsoni, 216
Ovis cervina sierrae, 216
Parophrys vetulus, 24
Paspalum distichum, 275
Phanerodon furcatus, 24
Pholisma sonorae, 62
Pinus jeffreyi, 107
Pinus lambertiana, 4, 107
Pinus longaeva, 154
Pinus monophylla, 154
Pinus ponderosa, 4, 106
Pinus spp., 2
Platichthys stellatus, 24
Pleuronichthys coenosus, 24
Pleuronichthys decurrens, 24
Polygonum spp., 275
Porichthys notatus, 23
Prosopis glandulosa, 159
Psettichthys selanostictus, 24
Pseudo-nitzschia australis, 179
Pseudotsuga menziesii, 4, 106
Puma concolor, 154
Quercus kellogii, 3, 107
Quercus spp., 2
Radulinus asprellus, 24
Raja rhina, 23
Rana aurora draytonii, 39, 257
Rana catesbiana, 257
Rana pipiens, 38, 39, 40

Rhacochilus vacca, 185
Rhinichthys osculus klamanthensis, 84
Salix spp., 229
Salmo salar, 48
Sardinops caeruleus, 180
Savelinus namaycush, 202
Sciaenops ocellatus, 48
Scirpus acutus, 260
Scirpus paludosus, 270, 275
Scirpus sp., 120
Sciurus griseus, 2
Scomber japonicus, 185
Sebastes auriculatus, 23
Sebastes babcocki, 213
Sebastes crameri, 23
Sebastes elongatus, 23
Sebastes entomelas, 23
Sebastes flavidus, 23
Sebastes goodei, 23
Sebastes melanops, 23
Sebastes paucispinis, 23, 184
Sebastes pinniger, 23
Sebastes saxicola, 23
Sebastolobus alascanus, 23
Sequoia sempervirens, 219, 229
Signaus fuscescens, 48
Siphateles bicolor, 83
Spermophilus beecheyi, 309
Sphaeralcea ambigua, 159
Spirinchus starksi, 23
Spirinchus thaleichthys, 23
Squalus acanthias, 23
Stellerina zyosterna, 24
Stipa speciosa, 159
Strix occidentalis, 3
Sus scrofa, 131
Tamiasciurus douglasii, 1, 2
Thaleichthys pacificus, 23
Thamnophis couchi gigas, 256
Thamnophis elegans, 120
Thamnophis gigas, 120, 255, 256
Thamnophis sirtalis fitchi, 264
Thamnophis sirtalis, 120
Thamnophis sirtalis, 256

Tiquilia plicata, 67
Torpedo californica, 23
Trachipterus altivelis, 23
Trachurus symmetricus, 24
Triakis semifasciata, 128
Tridentiger trigonocephalus, 57
Typha sp., 120
Typha sp., 260
Typhus spp., 275
Ulva, 188
Umbellularia californica, 229
Urechis caupo, 189
Xenertmus latifrons, 24
Zalophus californianus, 180

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